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AD NUMBER

ADB203975

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AUTHORITY

AFRL/HE ltr dtd 10 Aug 2007

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AL/CF-TR-1994-0056

ARMSTRONG LABORATORY

A HUMAN FACTORS EVALUATION OF THE MH-60G PAVE HAWK HELICOPTER COCKPIT (U)

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JANUARY 1994

FINAL REPORT FOR THE PERIOD APRIL 1993 TO JANUARY 1994

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NOTICES

DISCLAIMER

TECHNICAL REVIEW AND APPROVAL

AL/CF-TR-1994-0056

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

KENNETH R. BOFF, Chief
Human Engineering Division
Armstrong Laboratory

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
January 1994

3. REPORT TYPE AND DATES COVERED
Final April 1993 - January 1994

4. TITLE AND SUBTITLE
A Human Factors Evaluation of the MH-60G PAVE HAWK Helicopter Cockpit.

5. FUNDING NUMBERS
C: F41624-94-D-6000
PE: 62202F
PR: 7184
TA: 10
WU: 44

6. AUTHOR(S)
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Logicon Technical Services, Inc.
P.O. Box 317258
Dayton, OH 45431-7258

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Armstrong Laboratory, Crew Systems Directorate
Human Engineering Division
Human Systems Center
Air Force Materiel Command
Wright-Patterson AFB, OH 45433-7022

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
AL/CF-TR-1994-0056

11. SUPPLEMENTARY NOTES
*Logicon Technical Services, Inc.

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Distribution authorized to DoD Components only; Premature dissemination, 3 October 1993; Other requests for this document shall be forwarded to AL/CFHI, Area B, Bldg. 248, Wright-Patterson AFB, OH 45433-7022

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
This report documents several recommendations to improve functionality, decrease workload and ultimately improve overall mission performance through a human factors evaluation of the MH-60G cockpit. Utilizing the Tools for Automated Knowledge Engineering process and software tools, the MH-60G cockpit was evaluated for possible human factors related deficiencies and/or areas for possible improvement. The results of this evaluation provide guidance for current cockpit modifications. Tools for Automated Knowledge Engineering is a software tool that employs an advanced knowledge elicitation technique called concept mapping. It's computer supported analysis tools manage and engineer the information collected in concept maps. TAKE provides engineers, designers, and manages with an ability to quickly collect, analyze and display information in efficient data representations.

14. SUBJECT TERMS
Knowledge Acquisition, Knowledge Engineering, Concept Mapping, Concepts, Systems Analysis, Systems Design, Prototyping, User Requirements, Human Performance, Human Factors

15. NUMBER OF PAGES
138

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unlimited

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std Z39-18
298-102

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PREFACE

The Human Engineering Division of Armstrong Laboratories, USAF, conducted a human factors evaluation of the MH-60G PAVE HAWK helicopter cockpit at the request of SMOTEC/RW. This evaluation was conducted in two phases at Hurlburt Air Force Base with the cooperation of the 55th Special Operations Squadron.

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INTRODUCTION

The Crew Systems Integration Branch of the Armstrong Laboratory at Wright-Patterson Air Force Base was asked by SMOTEC/RW to perform a human factors evaluation of the MH-60G PAVE HAWK helicopter cockpit. The system is in various stages of modification and a strong desire exists to bring human factors, crew workload and flight safety issues to the forefront. While this evaluation comes at the tail end of a major modification, it is important that the issues raised in this report are recognized and incorporated in future developments of this aircraft system.

Background

The primary mission of the MH-60G helicopter is to search for, locate and recover combat air crew members and perform special operations missions in all environments. Missions are typically conducted at night and very often over water. In order to increase the mission effectiveness of the aircraft, a GPS-Navigation Upgrade is currently being implemented. The upgrade has provided the air crew member with a more capable and reliable navigation system that is much easier to use. Unfortunately, the changes that were incorporated into the cockpit as a part of this upgrade did not alleviate many of the human factors problems that were already present. In fact, the modification itself has created additional potential problems. One of the primary problems identified was the requirement to fly aircraft in different phases of modification. This causes crew members to have to search for instruments and controls during flight. Instrument location is dependent upon the particular modification they are flying. This problem will be alleviated as soon as all aircraft are upgraded to the GPS-NU version. There are, however, other problems with the MH-60G cockpit affecting combat effectiveness and flight safety.

Objectives

The objective of the evaluation was to identify human factors problems and provide recommendations to alleviate those problems. Two trips were made to the 55th Special Operations Squadron (SOS) at Hurlburt Field to collect data and assess the overall system. The first trip provided an opportunity to become more familiar with the MH-60G mission and the helicopter subsystems. Observations made during flight aided 1) the understanding of the platform and 2) subsystem utilization during the actual mission. The second trip provided an opportunity to collect more detailed information about the tasks performed and the controls and displays used within the cockpit. This information was collected through personal interview sessions and written questionnaires. The goal of the evaluation was to provide inputs that would enhance cockpit integration in order to increase air crew performance, combat effectiveness and flight safety.

METHODOLOGY

Preliminary Evaluation

The first trip consisted of interviews and observations during flight. A small group of pilots were interviewed to determine the overall mission profile for the MH-60G and to identify major problems in the cockpit. The mission profile consisted of several major events that take place during a typical mission. Examples of these events are Take Off, Navigation, Aerial Refueling, Night Water Hoist, and Landing. Flight Engineers and Gunners were interviewed using a verbal-graphical technique known as concept mapping. Concept maps were recorded on the tasks that they perform during each mission event and the major problems associated with those tasks.

In addition to the flights and interviews, a brief reach and vision analysis was conducted. Crew members were asked to sit in the MH-60G cockpit as they would during a typical mission to evaluate their ability to reach all the controls. Pilots were then asked to explain what they could see outside of the cockpit. It was discovered that the glare shield might be obstructing vision outside of the cockpit and that a more thorough vision analysis was in order.

After the first trip to Hurlburt, Major Jim Osborn traveled to Armstrong Laboratory at Wright-Patterson Air Force Base to undergo a series of detailed interview sessions. The purpose of these interview sessions was to identify and describe, in detail, the high workload phases of a typical MH-60G mission. Navigation, Night Water Hoist and Aerial Refueling were identified as the highest workload phases. Major Osborn described the tasks performed and the controls and displays used during these high workload mission segments.

Major Osborn also described the frequency of display and control use, the relative task workload, the cues available inside and outside the cockpit and the problems associated with specific controls and displays. All of this information was recorded on three concept maps, one for each of the high workload phases. These maps were printed out and later validated by Major Osborn before he returned to Hurlburt Field.

Primary Evaluation

The maps constructed from Major Osborn's descriptions were taken on the second trip to Hurlburt and shown to other pilots in the squadron for possible additions or changes. The maps and the outlines of those maps are shown in Appendix A and reflect the inputs of Major Osborn and other pilots in the 55th SOS.

The questionnaires had the pilots rate the adequacy/inadequacy of 17 different display/control panels (Display Type) on seven different Display Factors. The rating scale and their verbal equivalents were as follows: 1 = totally inadequate, 2 = very

inadequate, 3 = mildly inadequate, 4 = mildly adequate, 5 = very adequate and 6 = totally adequate. The 17 Display Types are listed in the Results section of this paper (see Table 2). The seven Display Factors and a short definition of each factor were included on each page of the questionnaire and are shown in Table 1. Questionnaires were administered to the pilots individually so they could complete them alone, in privacy. Questionnaire completion time was approximately one hour. The questionnaire is shown in Appendix B of this report.

Table 1. Display Factors with Factor Definitions.

Display Factor	Definition
Access	The accessibility of all of the controls on the panel
Location	The location of the panel within the crew station
Display Visibility	The visibility of the panel display
Lighting	The visibility of the panel lights
Label/Legends Legibility	The legibility of the panel labels/legends
Functional Grouping	Rate the functional grouping of the panel controls and displays
Operational Utility	What is your overall impression of the Operational Utility of the panel?

During the individual interviews the pilots were first asked to provide specific biographical data (aircraft flying time, MH-60G flying time, etc.) and then asked to look over one of the three high workload phase maps (navigation, aerial refueling or night water hoist) for additions or corrections. Pilots were then asked to discuss what they thought were the most significant problems associated with flying the MH-60G as related to the cockpit displays and controls configuration. This information was recorded in individual concept maps and in written notes.

At some point, either before or after the pilots' individual interviews, visual field of view (FOV) measurements were taken with the pilots seated in the cockpit of the aircraft. Pilots provided visual angle measurements over the cockpit glare shield and to the uppermost displays on the front console for several different seat locations and from their preferred seat location. This type of analysis allows prediction of pilot eye position (and therefore, visual capability) in the cockpit for a wide range of body sizes.

RESULTS

Questionnaire Results

Eleven pilots completed the Display/Control questionnaires. The pilots had an average of 2510 hours of flight time in various aircraft and 775 hours in the MH-60G. All had flown the most recent GPS-NU version. All of the pilots rated 15 of the 17 display panels. Approximately half of the pilots did not rate the two remaining panels because they had no experience using one or both of those particular panels.

The grand mean rating for all 11 pilots across both the Display Type and Display Factor variables was 4.62. This indicated that, overall, pilots felt the cockpit displays and controls were somewhere between mildly adequate and very adequate. The mean ratings for the Display Type and Display Factor variables were analyzed for their respective within-group differences. A within-groups ANOVA was conducted to determine the following: A) which Display Types were rated significantly higher or lower than other Display Types, B) which Display Factors were rated significantly higher or lower than the other Display Factors and C) which Display Factors were rated significantly different from the other Display Factors within each Display Type.

The pilots rated some of the Display Types significantly higher than some of the others across all of the Display Factors combined ($P=0.001$). The mean ratings for each Display Type are shown below in Table 2 and are shown graphically in Figure 1. Basically, the Fuel Management Panel and the Radios were rated significantly lower than almost all the other display panels. The SCU, Fuel Boost Pump, TACAN/NAV and FLIR panels were rated as being mildly adequate. The remaining panels were rated as being just under very adequate to close to totally adequate.

Table 2. Mean Adequacy Rating for Each Display Panel Averaged Across Display factor.

Display Type	Mean Rating
Head Down Display (HDD)	5.51
Engine Instruments (ENG)	5.45
Flight Instruments (FLT)	5.27
Radar Display Panel (RDR)	5.17
Mode Select Panel (MOD)	5.11
Altitude Hold Hover Stabilization (AHHS)	5.09
Control Display Unit (CDU)	5.06
Caution/Warning/Advisory (CWA)	5.05
Visual Symbology Display Sys (VSD)	4.85

Table 2 (cont'd)

Display Type	Mean Rating
Stabilator Control (STC)	4.68
Inter-communications System (ICS)	4.49
Forward Looking Infra-Red Panel (FLR)	4.36
TACAN/NAV Panel (TCN)	4.12
Fuel Boost Pump (FBP)	4.11
System Control Unit (SCU)	4.03
Fuel Management Panel (FMP)	**3.71**
Radios (RAD)	**3.02**

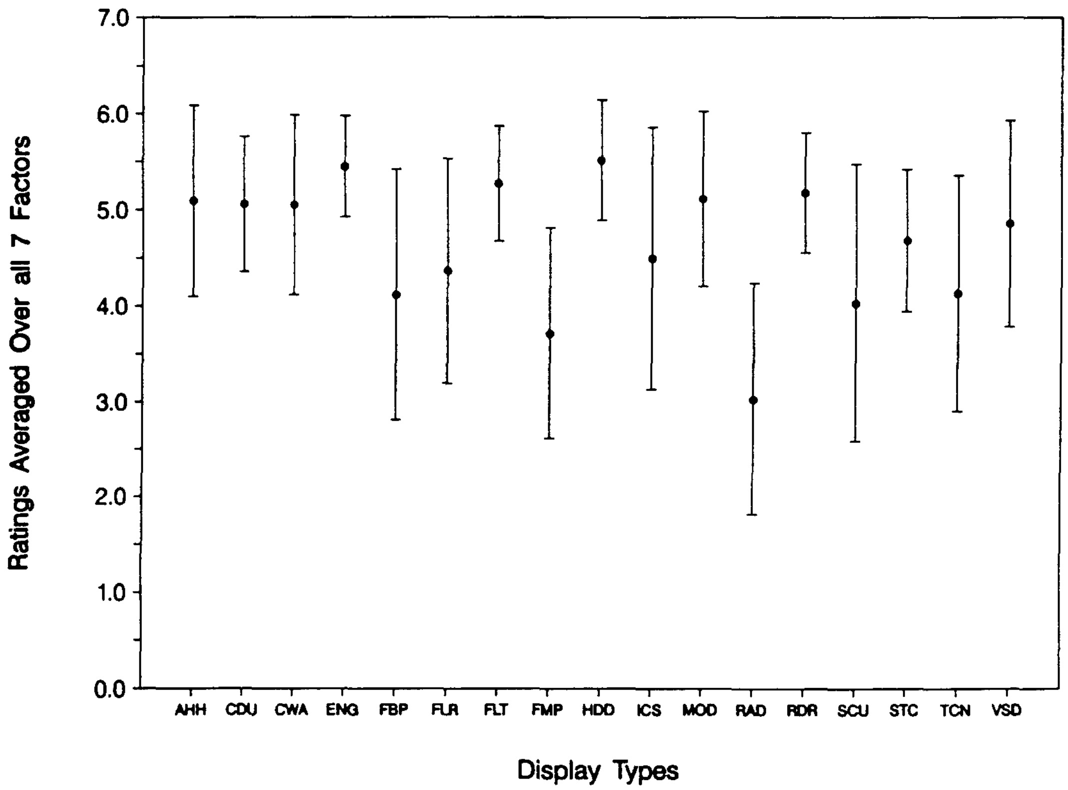

Figure 1. Mean Adequacy Rating for Display Type Averaged Across Display Factor.

There was a significant effect for the Display Factor variable (P=0.0049). The means are shown below in Table 3 and shown graphically in Figure 2. A Tukey post-hoc analysis showed the Lighting factor was significantly lower than all the other Display Factors except Visibility and Utility. No other Display Factors were significantly different from each other. Lighting was consistently rated the lowest across all the display types. The lack of good lighting in the cockpit could be responsible for the low ratings assigned to the Utility and Visibility Factors.

Table 3. Mean Adequacy Rating for Display Factor Averaged Across Display Type.

Display Factor	Mean Rating
Functional Grouping	4.78
Display Label Legibility	4.77
Accessibility	4.70
Location	4.69
Utility	4.67
Visibility	4.49
Lighting	4.19

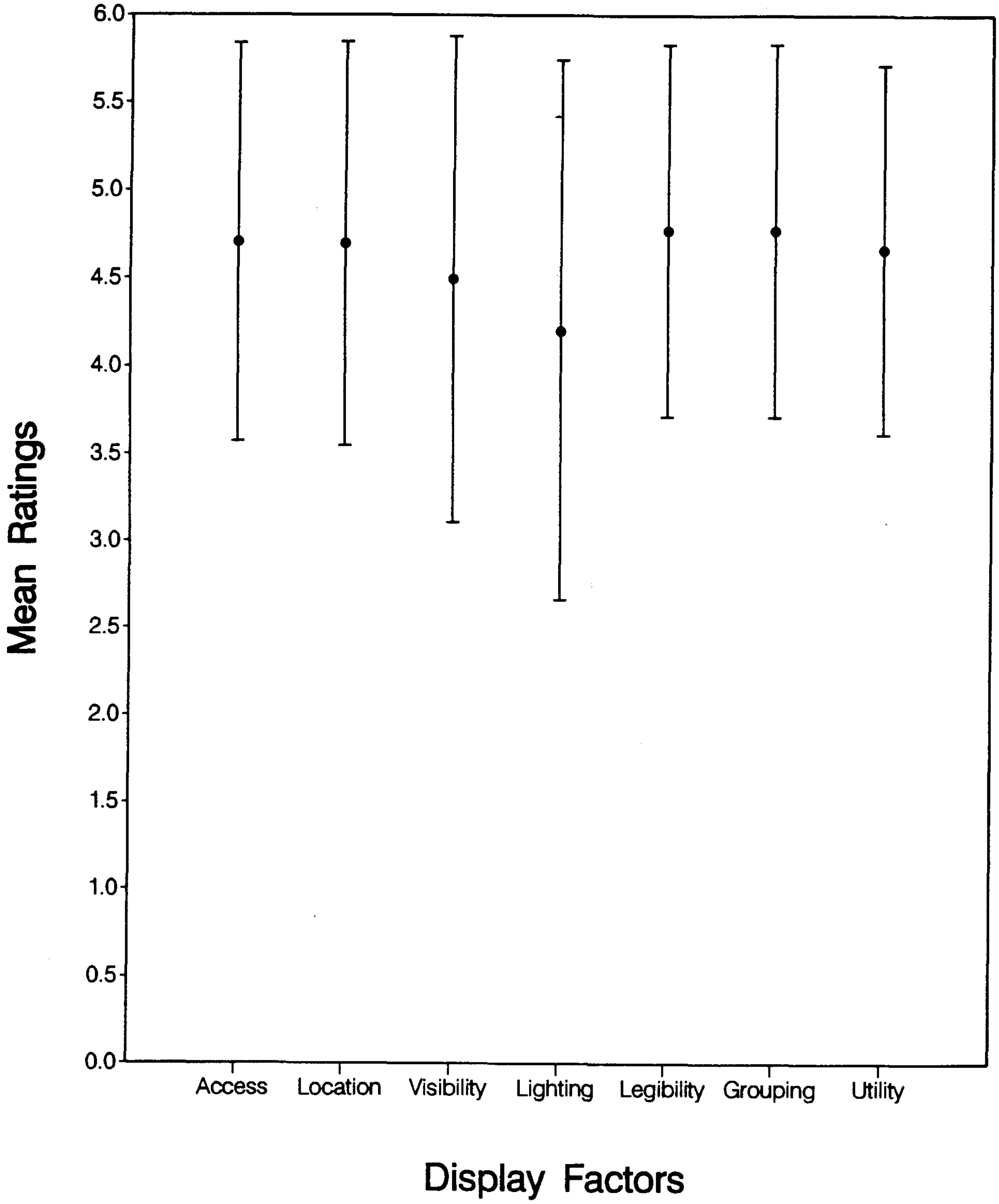

Figure 2. Mean Rating as a Function of Display Factor Averaged Across Display Type

Paired T-tests were performed on the ratings data to determine which of the Display Factors was significantly different from each other within each particular Display Type. The means of the Display Factors for each Display Type are shown below in Table 4. The results of the paired T-test analysis for each Display Type are described below with a description of the Display Type, a summary of the pilots' written comments and some recommended solutions.

Table 4. Mean Display Factor Ratings for each Display Type.

	Display Type				
Display Factor	HDD	ENG	FLT	MOD	AHH
Accessibility	5.45	5.50	5.36	5.10	5.33
Location	5.82	5.45	5.36	5.10	5.33
Visibility	5.45	5.45	5.27	5.40	5.00
Lighting	5.36	5.45	4.91	5.40	5.00
Legibility	5.36	5.27	5.36	5.20	5.00
Grouping	5.50	5.45	5.36	4.90	5.00
Utility	5.64	5.45	5.27	4.70	5.00

	Display Type				
Display Factor	CDU	CWA	RDR	VSD	STC
Accessibility	5.18	5.18	5.20	4.91	4.64
Location	5.45	5.18	5.20	5.00	4.64
Visibility	4.73	5.09	5.40	4.54	4.70
Lighting	4.82	4.45	4.75	4.54	4.50
Legibility	5.00	5.50	5.40	5.09	4.91
Utility	5.14	4.91	5.20	4.91	4.64

	Display Type				
Display Factor	ICS	FLR	TCN	FBP	SCU
Accessibility	5.27	4.54	4.18	4.00	4.00
Location	5.00	4.18	4.18	4.00	4.10
Visibility	4.18	3.91	4.09	4.18	3.70
Lighting	3.09	4.18	3.36	3.73	3.70
Legibility	4.91	4.73	4.36	4.36	4.20
Grouping	4.73	4.54	4.27	4.36	4.30
Utility	4.27	4.45	4.45	4.36	4.20

Table 4 (cont')

Display Factor	Display Type FMP	RAD
Accessibility	3.54	3.36
Location	3.27	3.27
Visibility	3.54	2.63
Lighting	3.09	2.00
Legibility	4.36	3.36
Grouping	4.18	3.18
Utility	4.00	3.36

1. Head Down Display (HDD)

The Head Down Display is located on the lower outside corner of the front console. It is used to display various types of information including heading, airspeed, digital altitude, analog altitude, low altitude warning, horizon reference, lubber line and helicopter centerline reference. Other types of information are displayed in different operating modes. This display panel and its bezel switches are us frequently.

The mean rating for the Head Down Display averaged across Display Factors was 5.51, the highest of all Display Type ratings. All the display factors were rated highly for this display. The pilots had very few negative comments except one pilot said that the torque power setting was hard to read, the HDD needed a Barometric Altimeter in the FLIR mode and it needed a good trim indicator. Some pilots reported that the controls should be backlit in order to make it easier to find the knobs.

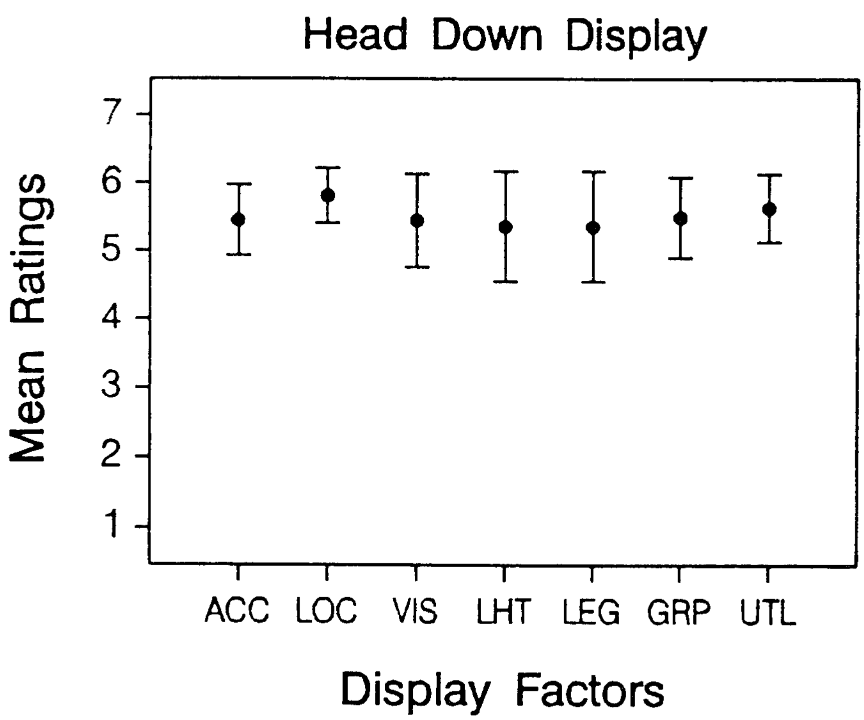

Figure 3. Mean Display Factor Rating for the Head Down Display.

2. Engine Instruments

The Engine Instruments panel is located near the center of the front console. This panel displays engine oil temperature and pressure, turbine gas temperature, gas generator, power turbine % Nf, rotor speed, engine torque and fuel quantity. The engine instruments are an integral part of the co-pilots cross check.

The mean rating for the Engine Instruments Display was 5.45. All the display factors were rated highly for this display. The Legibility Display Factor (5.27) was rated slightly lower than the other Factor ratings but not significantly so. The comments reflected this slightly lower mean in that pilots reported the legends were too small to read easily.

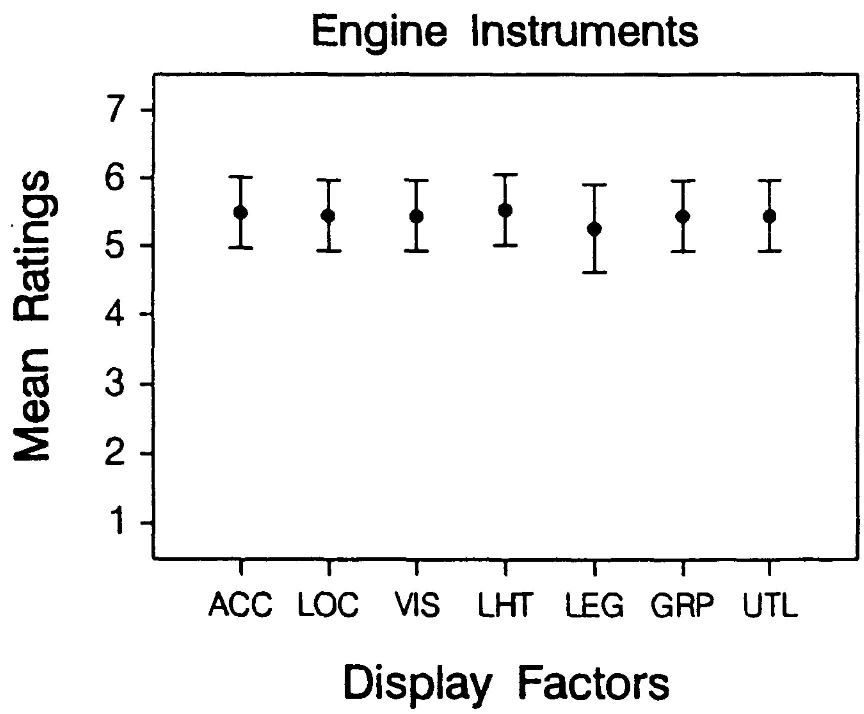

Figure 4. Mean Display Factor Rating for the Engine Instruments.

3. Flight Instruments

The flight instruments are located on the front console of the cockpit. The Course and Heading Select controls are used frequently. The mean rating for the Flight Instruments Display was 5.27. All of the Display Factor ratings (Avg. = 5.33) were approximately the same except for Lighting (4.90). Two pilots reported that the trim ball was poorly lit. Since it was indicated that the trim indicator on the HDD was not adequate, one of these indicators needs to be corrected to provide trim information. Trim calls are vital during hover and aerial refueling. This display must be easy to see in all conditions.

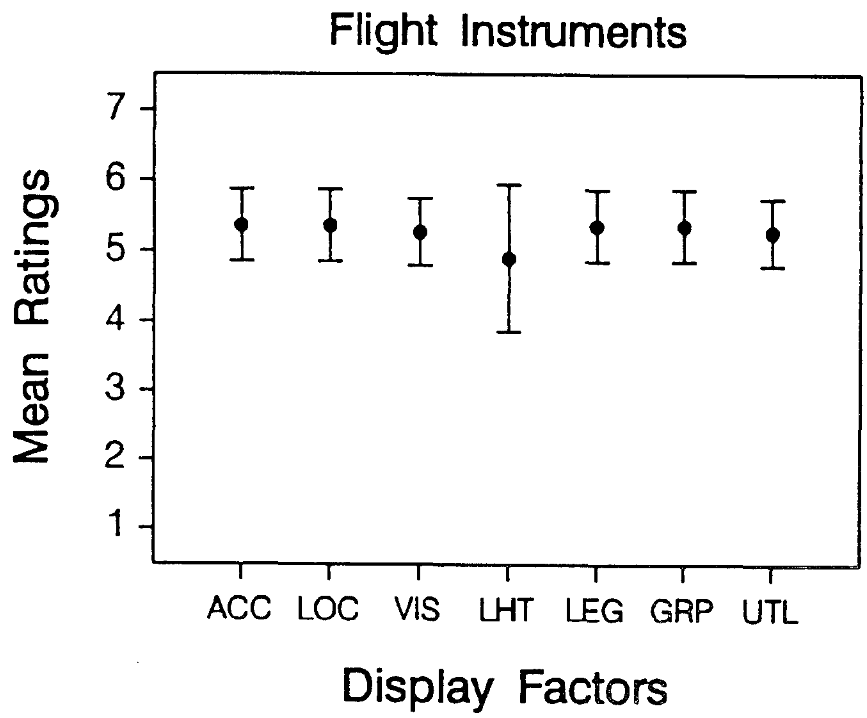

Figure 5. Mean Display Factor Rating for the Flight Instruments.

4. Mode Select Panel

There are three mode select panels; the Command Instrument System (CIS) mode panel, the Vertical/ Horizontal Situation Indicator (VSI/HSI) mode panel and the Navigation (NAV) mode panel. The CIS Mode Select panel is located on the right side of the front console midway between the center and outside of the console. It is used to select one of three modes of operation (Heading on, NAV ON and ALT ON) to direct navigational signals tō the Command Instrument System Processor for Command Signal display. The VSI/HSI Mode Select panel is located midway between the outside and centerline of both sides of the bottom of the front console. It is used to select various navigation functions. The two NAV Mode Select panels are located at the bottom - left of the front console. The NAV Mode Select panel is used in conjunction with the CIS and VSI/HSI Mode Select panels to select various navigation modes. All of the Mode Select panels are used frequently.

The mean rating for the Mode Select Panels was 5.11 indicating a high level of satisfaction with these panels, overall. None of the Display Factors was significantly different from each other within these panels. Comments concentrated on the fact that the NAV Mode Select shows "ILS" when flying a TACAN approach. Pilots thought this was both confusing and dangerous. They also reported that a problem resides in the fact that the CIS Mode Select panel used to select NAV/HDG/ALT was not accessible to the left-side pilot. There is adequate space to install CIS Mode Select Panel on the co-pilots side of the front console. The pilot has priority in selection, but he must deselect in order for the co-pilot to engage his CIS Select switches.

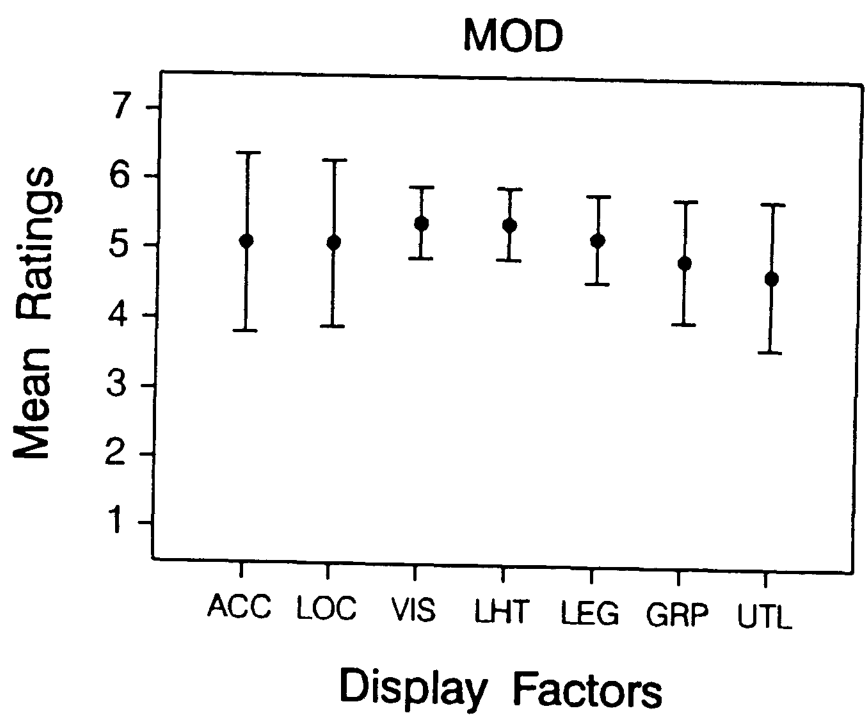

Figure 6. Mean Display Factor Rating for the Mode Select Panels.

5. <u>Altitude Hold Hover Stabilator (AHHS) Panel</u>

Only three of the eleven pilots queried responded to this panel because the others had never used this new system before. The three that did respond, however, gave it a mean rating of 5.09. None of the Display Factors was significantly different from one another. Those that have used the AHHS report that they liked it. Most of the other pilots reported that they were looking forward to the installation of this system because it will help reduce the difficulty of hovering steadily over water at night. This is reported to be one of the most difficult high workload tasks for the MH-60G pilot. The installation of this system will greatly reduce the workload associated with this highly critical task. However, as with any other subsystem, the system must be integrated intelligently into the cockpit. The logical place for this control is on or near the collective. The placement of the control in the cockpit should not be on a "space available" basis.

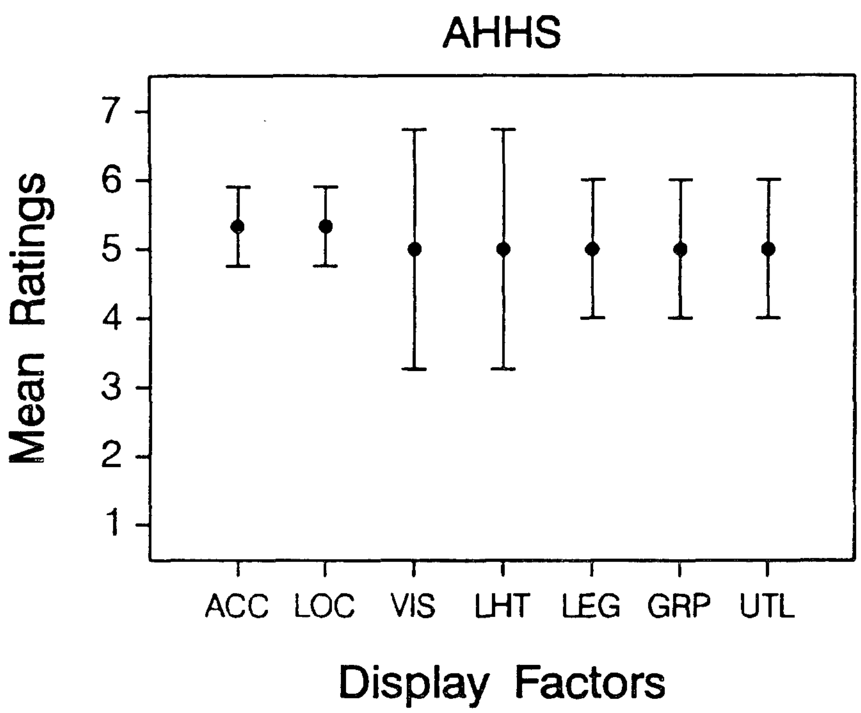

Figure 7. Mean Display Factor Rating for the Altitude Hold Hover Stabilator.

6. Control Display Unit (CDU)

The Control Display Units are located on the center console directly to the left of the pilot and to the right of the co-pilot. The CDUs display and permit operator entry and modification of numerous types of mission data. The CDUs are used often during the various MH-60G missions.

The overall mean rating for the CDU was 5.06. Within this Display Type the Location Factor was rated highest at 5.45. Visibility and Lighting were rated the lowest at 4.73 and 4.82, respectively. These means were not significantly different. One problem reported by the pilots was that the keypad for data entry was a non-standard keypad which necessitates learning new key positions and could affect data input performance in times of high stress. Several reported that they had to lean over and position their head directly above the display to read it and they still had to use finger lights. Suggestions were: 1) tilt the display toward the pilot/copilot and 2) improve lighting so finger lights would not be necessary.

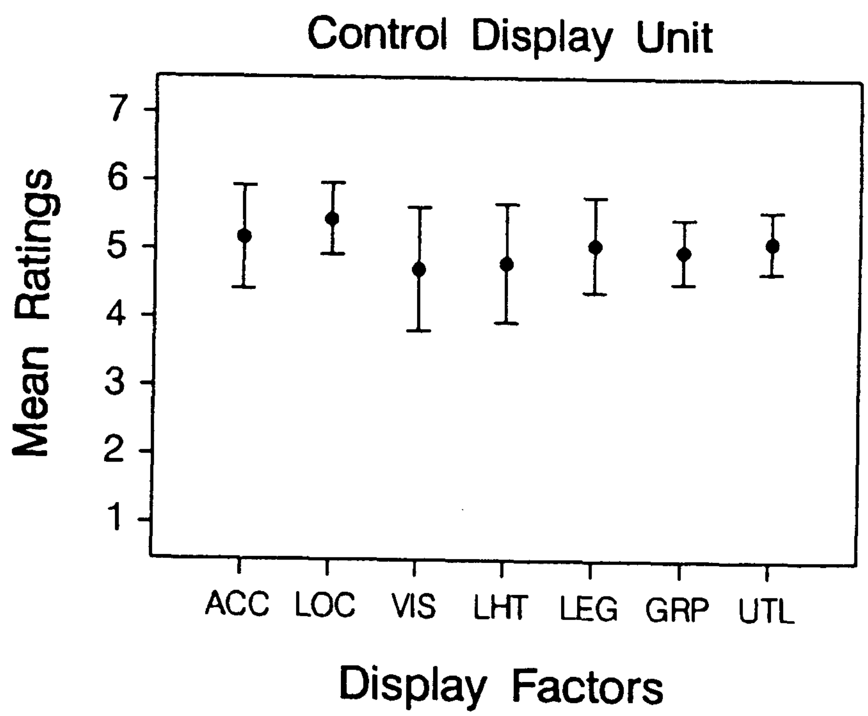

Figure 8. Mean Display Factor Rating for the Control Display Unit.

7. <u>Caution/Warning/Advisory (CWA)</u>

The Caution/Warning/Advisory panel is located just to the left of the center of the front console. The caution section (upper two-thirds) of the panel indicates certain malfunctions or unsafe conditions with amber lights. The advisory section (lower third) shows certain non-critical conditions with green lights. This panel is considered a critical-use panel.

The overall mean rating for the CWA was 5.05. Both the Lighting and Utility factor means (4.45 and 4.91, respectively) were found to be significantly lower than the functional grouping mean (5.50). Several lighting factors were considered inadequate by the pilots. The blinking of the "Auxiliary Fuel" light was called "unacceptable, distracting and sometimes dangerous." Pilots report that poor lighting and legibility made the panel difficult to read in bright sunlight or low level lighting. Several pilots indicated this panel needs to be made NVG compatible. Proper lighting of this panel is critical. This is a safety of flight issue that needs to be corrected.

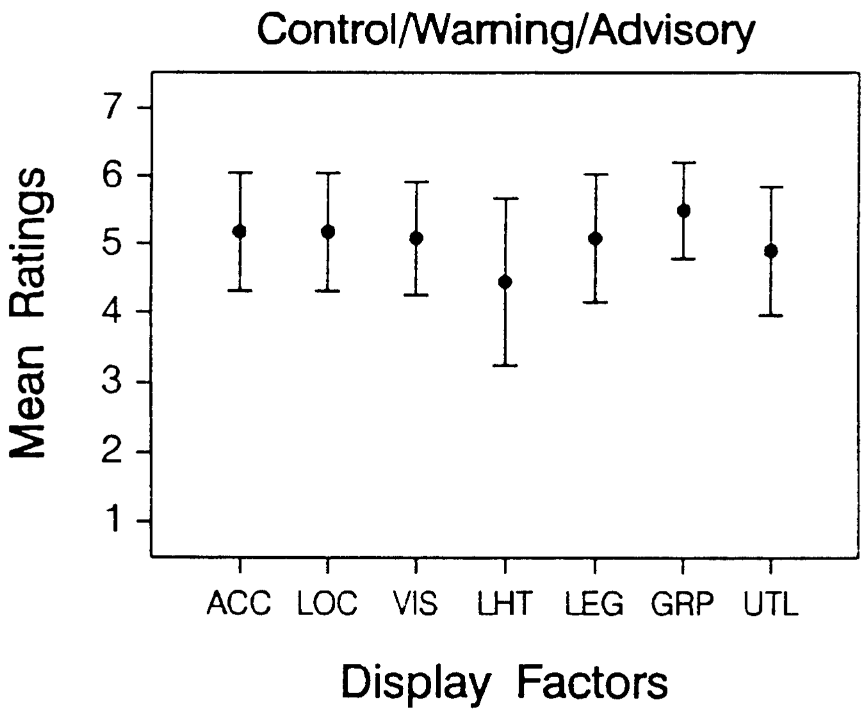

Figure 9. Mean Display Factor Rating for the Caution/ Warning/Advisory Panel.

8. Radar Panel

The Radar panel is located immediately to the right of the center of the front console just below the engine instruments panel. This panel interfaces with the inertial and GPS-NU navigation systems. It receives and displays several types of navigation information. The Radar panel controls also provides for five primary modes of operation: three air-to-surface search and detection modes and two conventional weather avoidance modes. The Radar panel is used frequently.

The overall mean rating for the Radar panel was 4.96. None of the means associated with the display factors was significantly different from one another. Lighting was rated the lowest (4.75) and Grouping and Visibility were rated the highest at 5.40 each. Most pilots comments indicated they had no problems with this panel, although a couple said it was not lighted and should be.

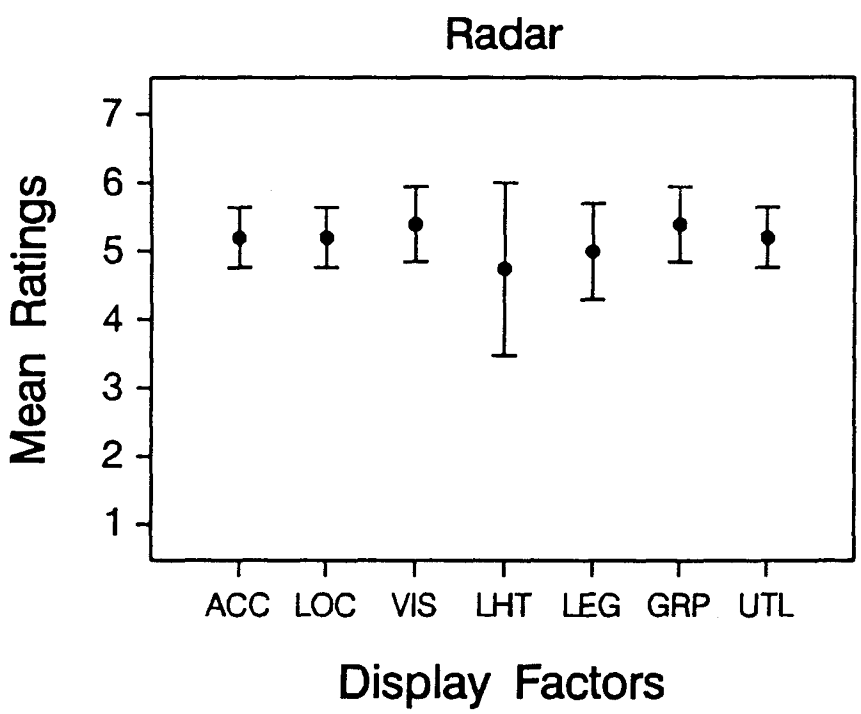

Figure 10. Mean Display Factor Rating for the Radar panel.

9. Video Symbology Display System (VSD)

The VSDS interfaces with the helicopter avionics system and 1553B bus to generate multi-mode symbology displays that are superimposed onto the field of view of the night vision goggles. The symbology displays are also integrated with the FLIR video for presentation on the video monitors.

The overall mean rating for the Video-Symbology Display System was 4.86. None of the display factor means was significantly different from one another. Both Lighting and Visibility were rated the lowest (4.54 each) and Functional Grouping was rated the highest (5.09). One pilot commented that having to take his hands off the control stick to switch the VSDS into declutter mode was unsafe. Most other pilots reported no disatisfaction with this panel.

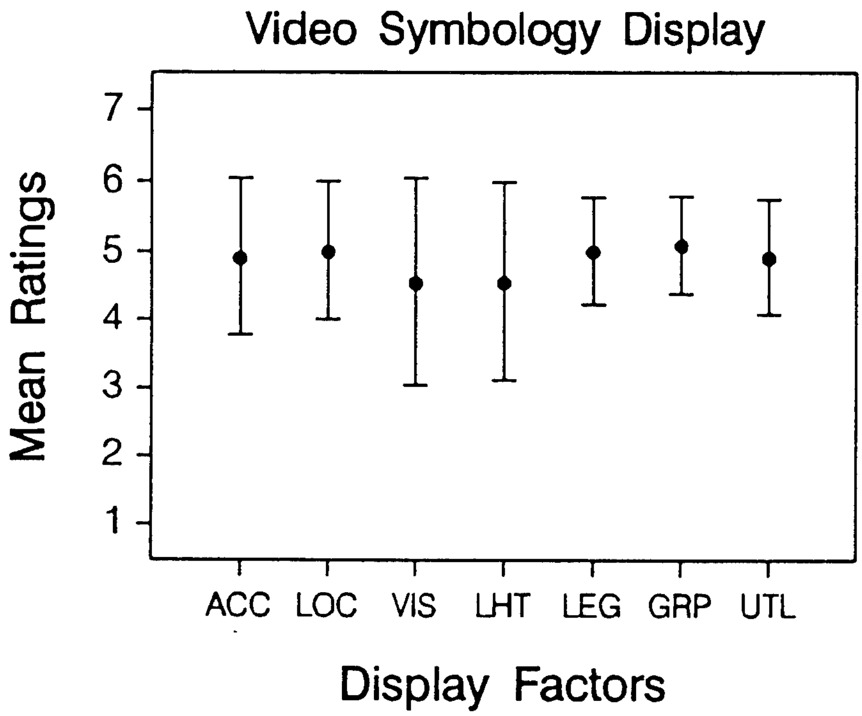

Figure 11. Mean Display Factor Rating for the Video Symbology Display System.

10. Stabilator Control Panel (STC)

This panel provides electrical control of the stabilator system. The stabilator system improves flying quality through positioning of the stabilator by means of electromechanical actuators in response to the collective, airspeed, pitch rate and lateral acceleration inputs. The panel also contains the controls for the Automatic Flight Control System (AFCS). The AFCS enhances the stability and handling qualities of the helicopter through control of the pilot-assist servos and actuators. This panel is not used frequently but is considered a critical-use panel in specific types of emergencies.

Without the AHHS installed, the Stabilator Control Panel is located in the center of the lower console just behind the FLIR control stick. With the AHHS installed just behind the FLIR control stick, one possible location for the stabilator Control Panel is in front of the FLIR control stick, between the two CDUs.

The overall mean rating for the Stabilator Control panel was 4.68. None of the Display Factor means was significantly different from one another. Lighting was rated the lowest at 4.50 and Functional Grouping the highest at 4.91. Comments for this panel indicated that most pilots thought there were no problems except that the panel itself was not standardized among aircraft. A couple of pilots said that the accessibility was a problem for the pilot. Accessibility and Location were both rated second lowest (4.64) among the Display Factors.

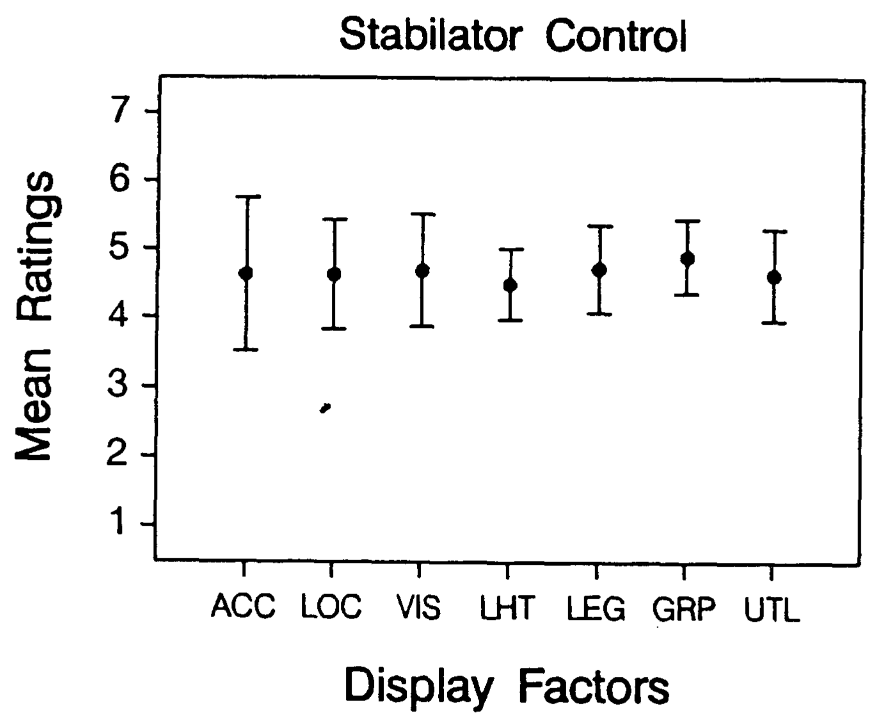

Figure 12. Mean Display Factor Rating for the Stabilator Control Panel.

11. Intercommunication System (ICS)

The two intercommunication system panels are located on the lower console just behind each CDU and on opposite sides of the FLIR control stick. This panel provides for A) interior intercommunication capability between crew members and B) a means by which the pilot and the copilot may select and control associated radio equipment for voice transmission and reception. The ICS is used quite frequently.

The overall mean rating for the Intercommunication System was 4.49. As can be seen in Figure 13 below, the mean rating for the Lighting factor (3.09) was lower than all the other factor means (4.18 - 5.27). These differences were significant ($p = 0.024$ through 0.002). Utility was significantly lower than Accessibility ($p = 0.0014$). A majority of the pilots complained that this panel was not backlit and therefore, could not be read at night. They considered this condition to be dangerous and mission threatening. Another complaint was that the volume could not be turned up loud enough and that the audio transmission needed to be a lot clearer (free of noise). One pilot reported that 20 - 30% of the time he doesn't completely hear what is transmitted. These are problems that must be addressed as soon as possible. The amount of crew coordination and communication required in the Pave Hawk mission demands a reliable intercommunication system.

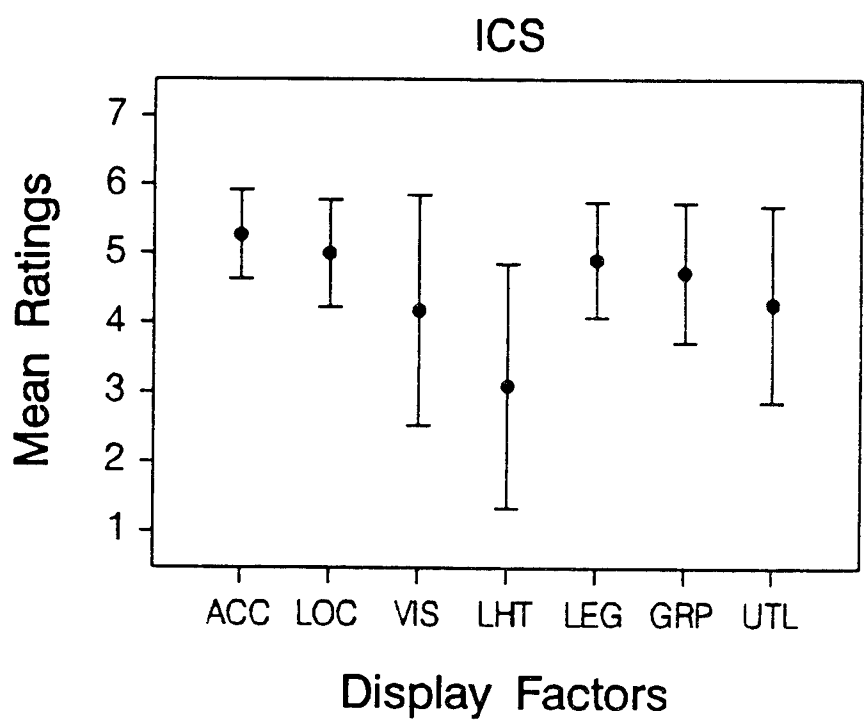

Figure 13. Mean Display Factor Rating for the Inter-communication System.

12. Forward Looking Infra-Red (FLIR) Panel

The FLIR display panels are located on the front console. The FLIR control panel is located on the aft console. Infra-red energy is converted to TV video and displayed on the two panels. The display panels are used for the passive infra-red detection, recognition, identification and classification of targets, scenes or activities that would otherwise be concealed by darkness or camouflage.

The overall mean rating for the FLIR control panel was 4.36. No Display Factor means were significantly different from one another. Visibility was rated the lowest (3.91) and Legibility the highest (4.73). This control panel is located on the aft panel, which makes it hard to access both physically and visually. Also, new capabilities have been added to the panel which has resulted in a relabeling of several buttons. This has required more memorization on the part of the pilots. Increased memorization requirements plus any carry over effects from previous configurations could very likely increase the cognitive workload associated with operating this panel. The control panel should be moved to a more accessible location. Crew members should receive additional ground training to become familiar with the new FLIR system capabilities to alleviate the negative transfer of training effects.

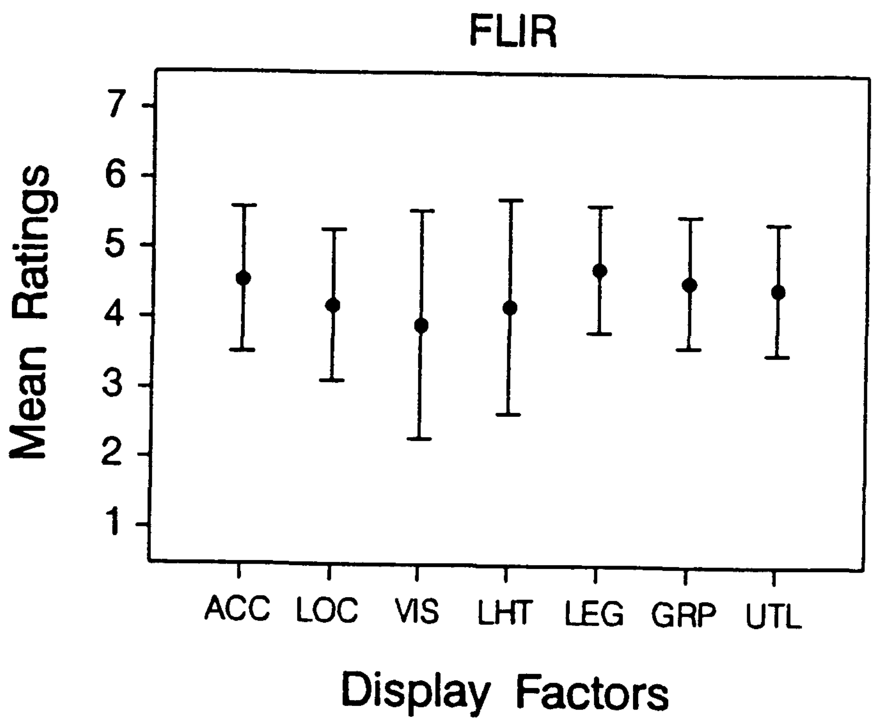

Figure 14. Mean Display Factor Rating for the Forward Looking Infra-Red Panel.

13. TACAN/NAV (TCN) Panel

The TACAN Control Panel is located in the middle of the aft section of the lower console. The panel is used to control the TACAN navigation system. The TACAN navigation system is a polar coordinate navigation system that is used to determine the relative bearing and slant-range distance to a selected TACAN station. This is presently a frequently used panel, however, its use could decrease once all the MH-60Gs are outfitted with the-GPS-NU navigation upgrade.

The overall mean rating for the TACAN/NAV panel was 4.13. Lighting was the lowest rated factor at 3.36. The difference between Lighting (3.36) and Visibility (4.09) was significant ($p = 0.012$). The difference between Lighting and the other factors was just as great or larger, however, the variability of those mean ratings was too great for them to be significantly different in the statistical sense. The largest complaint was that the lighting was very poor for night operations. The lighting is presently not NVG compatible but needs to be. Another complaint was that the steps required to provide a TACAN, VOR or ILS guidance update combined with the way the switches are marked make this task too difficult. The pilot said it was easy to forget or miss a switch.

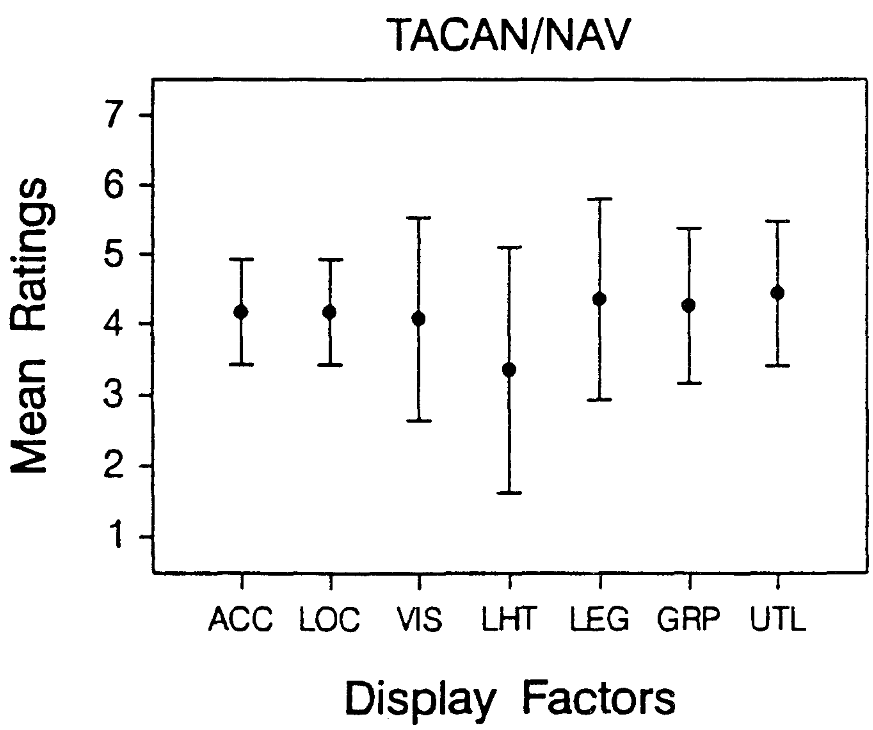

Figure 15. Mean Display Factor Rating for the TACAN/NAV Panel.

14. Fuel Boost Pump (FBP) Panel

The Fuel Boost Pump control panel is located on the forward-middle portion of the aft console. It is used to maintain constant fuel pressure at the engine fuel inlet port, regardless of engine boost pump discharge pressure. This panel is considered an emergency control whose frequency of use is low but whose criticality is high.

The overall mean rating for the Fuel Boost Pump panel was 3.71. Lighting was again the lowest rated factor (3.72) while Legibility and Functional Grouping were the highest (both 4.36). None of the Display Factor means were significantly different from one another. Location was rated second lowest of the Display Factors at 4.00. Pilot comments reflected this in that most of the complaints centered around the poor location of this panel. Most complained that it was difficult to reach. Others complained that it was mounted upside-down so the labels would match the right engines.

Although the location might not be an issue due to the fact that the panel is not used much, one pilot reported that during Emergency Engine Shutdown/Failure with the Fuel Direction in "cross-feed" it was easy to turn off the wrong switch. This could be a fatal error. Another consideration is that during fuel supply system specific emergencies it becomes a critical control and must be accessed quickly and easily. It's location should be changed to one that is more accessible.

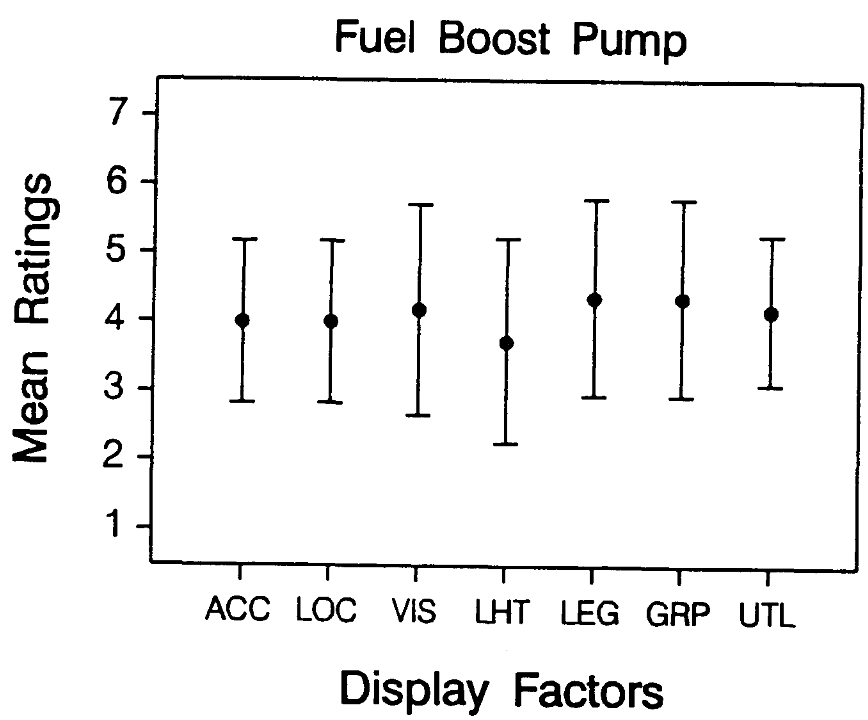

Figure 16. Mean Display Factor Rating for the Fuel Boost Pump panel.

15. System Control Unit (SCU)

The System Control Unit is located in the middle-aft portion of the aft console. It contains the ON/OFF control, system status indicators and built-in-test (BIT) control for the Forward Looking Infra-Red (FLIR) Detecting System. This panel is used relatively frequently depending upon the situation.

The overall mean rating for the System Control Unit was 4.03. Lighting and Visibility were the lowest rated Display Factors at 3.70 each. Functional Grouping was the highest at 4.30. None of the Display Factor means were significantly different from each other. Comments concerning this panel indicated that the pilots thought that it needed back lighting for night operations and that the location of the panel (on the aft console) was bad. This control panel needs to be moved to a more forward location and the lighting needs to be improved.

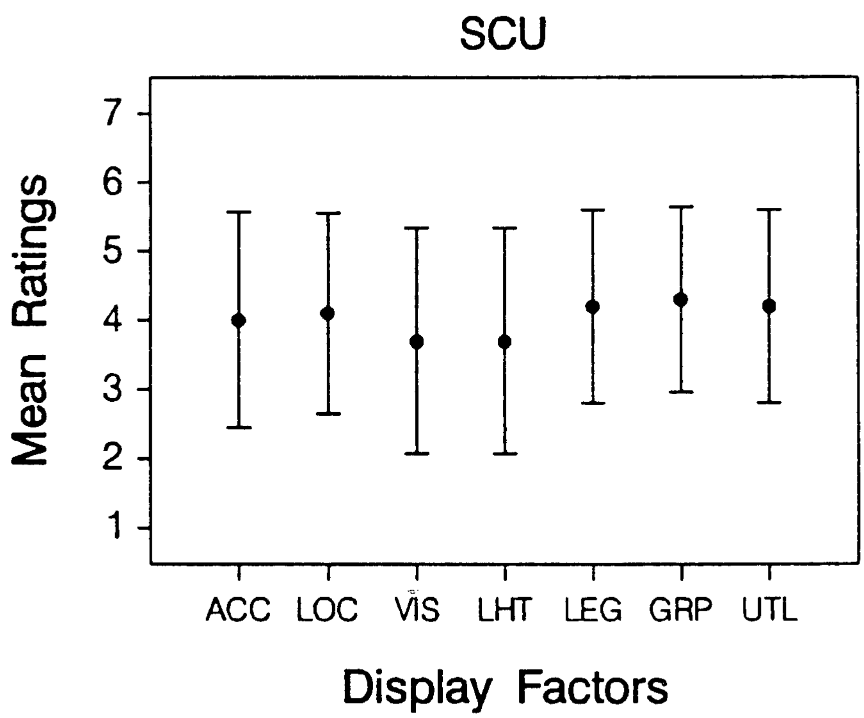

Figure 17. Mean Display Factor Rating for the System Control Unit.

16. Fuel Management Panel (FMP)

The Fuel Management Panel is located in the middle of the aft console. The FMP enables the crew member to control and monitor fuel dumping, external fuel tank jettison, ground pressure refueling, aerial refueling and fuel transfer. This panel is used frequently in support of aerial refueling, a relatively high workload task.

The overall mean rating for the Fuel Management Panel was 3.71. The ratings for the two lowest rated display factors for this panel, Lighting (3.09) and Location (3.27), were both significantly lower than the two highest rated factors (Functional Grouping (4.18) and Legibility (4.36)) (Lighting: $p = 0.04, 0.02$; Location: $p = 0.005$ & 0.006, respectively). Accessibility was found to be significantly lower than both the Legibility ($p = 0.01$) and Functional Grouping (0.026) factors. It was found, however, that only five of the 11 respondents actually rated Grouping higher than Accessibility while the remaining six rated Grouping and Accessibility the same. This casts some doubt on whether the two group means are truely different from each other for this particular panel. A graph of these results is located in Figure 18 on page 27.

Again, one of the major complaints was the bad lighting for night operations. The controls need to be backlit. The location of the panel on the aft console was considered poor also. There were complaints that 1) during aerial refueling, the operator had to take his eyes off the tanker to monitor the fuel overflow light/indicator, 2) the pilots can't read the switches because they are upside-down and 3) the panel location makes it easy to forget to stop a fuel transfer after one has been started (one pilot said "it happens all the time"). All of these problems are unacceptable. Flying at night, in formation, performing aerial refueling demands that the pilot be able to keep his eyes "outside" the cockpit at all times. Taking them "inside" to monitor the overflow indicator or to decipher the upside down switch labels is dangerous and threatens not only the success of the mission but also reduces flight saftety. The panel should be NVG compatible. The panel should be more accessible. The panel switch labels should be oriented properly so that crew members do not have to mentally rotate them to read them.

17. Radios (RAD)

The overall mean rating for the Radios was 3.02. This was, again, significantly lower than almost all of the other control/ display panels ($P<0.05$). Within this display/control panel, Lighting (2.00) was rated significantly lower than Accessibility (3.36), Functional Grouping (3.18), Legibility (3.36), Location (3.27) and Utility (3.36) ($p = 0.0006, 0.03, 0.03, 0.0009$ & 0.01, respectively). Visibility (2.64) was rated significantly lower than both Accessibility (3.36) and Location (3.27) ($p = 0.037$ & 0.045, respectively).

There were several complaints about this panel. The most prevalent complaint concerned the location of the radios. Most pilots reported that the radios were spread out all over the cockpit. Pilots presently have to turn their heads to the back to operate most of the radios, which takes their eyes away from the "outside." This is extremely hazardous when flying low level at night. All the pilots recommended that the radios be integrated into one communication unit. This would not only reduce the difficulty of finding and operating the radios but also create more space on the forward section of the aft console. The integrated communications unit could be placed on the forward section of the aft console. This would leave space on the back portion of the aft console for displays and controls that are not used frequently and/or are not critical to mission completion.

The second most prevalent complaint was the radio controls were very difficult to read during night operations. The poor Lighting rating was reflective of the pilot's desire to have controls and display backlit at an NVG compatible level for night operations.

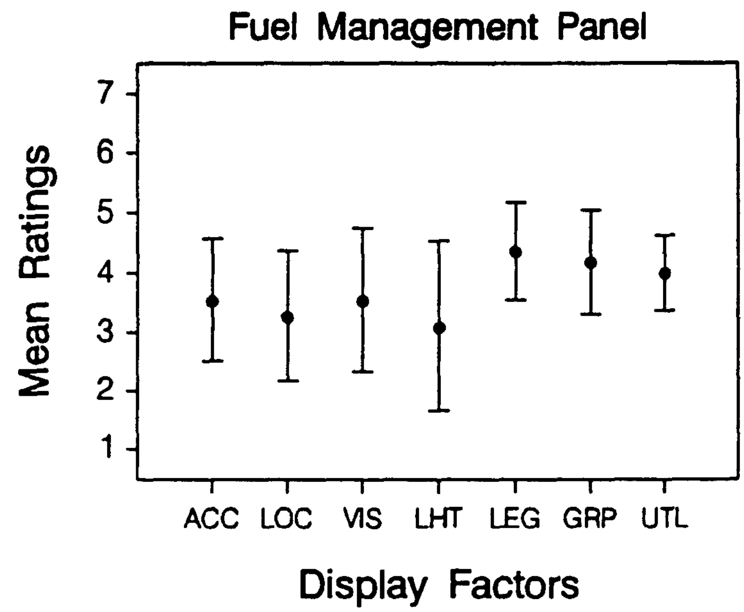

Figure 18. Mean Display Factor Rating for the Fuel Management panel.

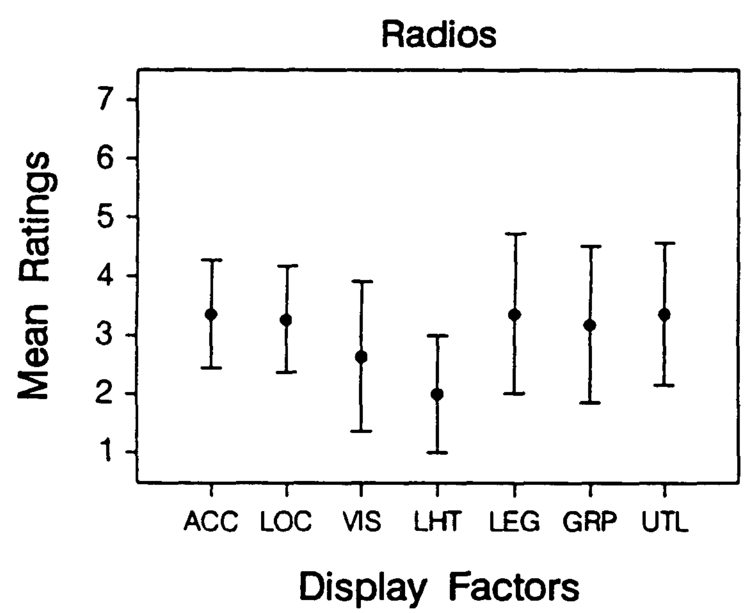

Figure 19. Mean Display Factor Rating for the Radios

Cockpit Visual Field of View Analysis

Most pilots selected a seat position where they were able to see 17 degrees over the nose of the aircraft. The visual field of view (FOV) data indicate that a modification of the angle of the glare shield relative to the main instrument panel would increase the pilot's downward or "depressing" FOV by at least 7 degrees. (See Roscoe and Hull, 1982, for a detailed description of "depressing" FOV). This means that with the glare shield in its present configuration and the aircraft positioned at an altitude of 100 feet, the pilot would be able to see the ground a minimum of 327 feet in front of the aircraft. With the glare shield modification, the additional seven degrees of FOV would allow the pilot to see the ground a minimum of 224 feet in front of the aircraft from the same seat position. This would greatly enhance a pilot's ability to search for targets of interest which are close to the aircraft and therefore, more easily detected, especially at night. Alternatively, the pilot could lower the seat to take advantage of cockpit armor, while retaining the original FOV.

Another option would involve designing an adjustable glare-shield that each pilot could adjust prior to flight or even remove prior to night operations. This assumes that there is no windscreen glare (reflection) coming from the cockpit lighting. Engineering drawings of the MH-60G cockpit were not obtained in time for inclusion in this report. However, they will be included in the Technical Report published by Armstrong Laboratory in early 1994.

CONCLUSIONS

Gunner and Flight Engineer Operations

The ability of the crew in the rear of the aircraft to quickly and efficiently perform their work appears to be greatly related to the space available. When the aircraft is loaded with ammunition and passengers, there is a minimal amount of room in the rear for the air crew to move about while performing their duties. Since the aircraft structure cannot change at this point, the key is to maximize use of the available space. A number of areas are discussed below which should help this situation.

Guns.

One of the gunners informed us of a serious hazard associated with operating the mini-guns presently mounted on the MH-60G helicopter. The hazard involves the possibility of an electrical short occurring in either the Gun Control Unit (GCU), Gun Drive Motor and/or the associated power cables electrifying both the gun and the all metal gun mount. The amount of electricity passing through the gun and/or gun mount as a result of an electrical short is easily enough to kill the gunner operating that gun. This particular gunner submitted a hazard report after a short did occur in one of the power cables. The electrical short was caused by a chaffing of the power cable by some of the gun mount components. Luckily, no crew members were injured because the short occurred low on the gun mount. Had the short occurred higher on the gun mount the operator would have been killed or, minimally, severely injured.

Temporary fixes include 1) adding a rubber spacer to the existing gun hand grips to keep the gunner's hands from contacting the cross member of the hand grip and 2) slide rubber hand grips on to the presently, all metal, hand grips.

Permanent fixes include 1) modify the existing MH-60G gun support arm and slider assembly to accept the M-93 mount assembly used on the UH-1N and MH-53J and 2) develop a pintle mount based on the current base plate and pivot arm assembly used for the .50 caliber gun. Both of these fixes would alleviate many of the problems delineated in the USAF Hazard Report submitted by one of the crew members we interviewed. This hazard report is shown in Appendix C of this report. Gunners reported that implementation of either one of the above permanent fixes would result in guns that would 1) be easier to use, 2) produce more accurate hit rates, 3) provide more efficient and safe expulsion of ammunition links and casings, 4) provide a larger field of view and 5) stow more easily and with more resultant room/space to conduct other back-end duties.

Three more complaints were heard consistently about the mini-guns. First, a modification has been made which moved the guns further outside the aircraft. This move has improved visibility and reduced the number of ammunition links falling inside the aircraft. However, the gun is now difficult to reach (particularly if

it needs to be worked on in flight). Most of the air crew felt that a position midway between the original and modified positions would be much better. Another suggestion is to develop some type of "elbow" in the mounting support to allow the gun to be pulled closer into the rear compartment to be repaired. Since the gunner is putting his head out into the wind stream to work on the gun or to improve his outside vision capabilities, a small fairing could be added in front of the side window to divert wind blast. The second problem was with the gun cables. Some are very long and tend to tangle with the gunners feet or bunch up over the ICS floor switch. Some simple clips or fasteners on the bulkheads of the aircraft could be used to keep the cables out of the way. A third problem identified by crew members was the fact that the pin which maintains the vertical position of the gun is not very strong and breaks down quite often. It should be easy to obtain stronger pins that would provide better support for the mini-gun.

General Clutter. In addition to the gun cables, a number of other obstacles are present which make it difficult for gunners and engineers to move about the aircraft. Ammunition cans, links from expended rounds, passengers, cargo, and the large SATCOM radio all restrict air crew mobility. This lack of mobility makes it difficult for them to clear jammed guns, or to look out the side doors to provide extra eyes for the pilots. Pilots, flight engineers, and gunners had several complaints about the archaic SATCOM radio. A new SATCOM radio is needed not only to improve communication, but also to save much needed space in the rear of the aircraft. A central ammunition can, which was tried in the past, makes sense if it is sized to allow rapid access to clear jams, and can be positioned far enough forward to maximize space for passengers. Overhead space and floor space should be kept clear as much as possible to avoid snagging the NVGs, minimize tripping hazards and maximize space for cargo and passengers.

Seat. The seat back and seat pan form a 90 degree angle. This seat design is not very comfortable. Also, as with the pilots, the battery pack for the NVGs interferes with the seat headrest making head movement difficult. Finally, the crash support structures under the seat can hook the air crews' feet when moving about. An interesting approach to solving a number of rear cabin problems could be using a seat similar to the V-22. This seat is also "crash worthy," but, the stroking mechanisms are in the seat back rather than under the pan. This allows the V-22 seat pan to be folded up when the crew member needs to move around. One solution is to attach the seat back structure to the ammunition can to minimize wasted space. The seat problem could be solved by increasing the seat back angle and the head rest area (unless an alternate site for the NVG battery pack could be found). The distance from the lower seat back (seat reference point) to the bulkhead should be around 28 inches. That value is the largest Buttock-knee length expected to fit into this seat. Anything less will cause the gunner to sit somewhat sideways in the seat.

Passenger Space. From 5 to 12 passengers (with their gear) may be carried in this aircraft. Air crews report having to share their seats with passengers when full. Any improvement to the size or shape of the extra fuel tanks inside the aircraft

would be a help. Also, the raft is very large and bulky. Crew members admit that the rafts are subject to a great deal of abuse because they are always smashed, contorted and stuffed into various places in order to secure them and get them out of the way. Crew members expressed concern about the condition of the rafts as a result of this abuse. If a smaller (or a vacuum packed) raft could be used, it would be a help. Again, ammunition cans spread around the gunners station and the large SATCOM radio waste valuable space. The external hoist is a big improvement in space utilization over the internal one.

Reach. With the exception of the new gun position, the only comments about reach problems were that the side door handles were inaccessible when the doors were open, and that the hoist cable was very difficult to stabilize while holding the hand controls.

Hoist Control Panel. There were several concerns with the hoist control panel, the pendant grip panel and their proposed modifications. One concern was the conflict between the controls for the internal and external hoist assemblies. Pushing the control on one panel raises the cable, while the same control action on the other assembly lowers the cable. Another concern lies in the fact that the location of the overhead panel makes it difficult to reach and guide the hoist cable while operating the hoist. Presently, one has to operate the hoist controls while simultaneously using both hands to pull cargo or passengers into the cabin. Consequently, crew members use the pendant grip so they can get closer to the door, see what is going on, and stabilize the cable. During these operations, the crew members find it very difficult to stabilize themselves and keep a hand on the cable, lean out the door and guide the payload. The importance of stabilizing the cable and guiding the payload cannot be over-emphasized enough because it has been linked to a mishap. Some sort of hand hold is very important and should be a priority. In addition, the pendant is too bulky and requires too much sustained thumb pressure to operate. The pendant should be more efficiently designed.

Pilot/Copilot Operations

Several of the display/control panels appear to be quite satisfactory to the pilots. These include the Head Down Display, the Engine Instruments panel, the Flight Instruments panel, the Radar Display panel and the Mode Select panel. However, the results of the questionnaire also indicate the need for several modifications to the current cockpit. Recommendations for modifications are primarily based on the nature of the MH-60G helicopter mission. That is, at night, oftentimes over water and mostly at low level altitude. The pilot needs to be constantly aware of the helicopter's position in relation to its surroundings. Therefore, the pilot needs to keep his/her vision "outside" the cockpit as much as possible. Any increase in time spent "outside" the cockpit visually is an increase in mission performance and safety.

Some specific recommended modifications are as follows. Tilt the Control

Display Unit toward the pilot/copilot to prevent the CRT screen glare from interfering with reading the display. Modify the volume control on the Intercommunication System so that each operator can adjust it to his/her satisfaction. Reduce the amount of noise presently existing in the ICS system. Pilots are not hearing all of what is being transmitted. This could result in a life or mission threatening miscommunication.

Modify the steps necessary to provide a TACAN, VOR or ILS guidance and the switch markings to reduce both the task difficulty and likelihood of forgetting or missing a switch.

Move the FLIR panel, the System Control Unit, which controls the FLIR, and the Fuel Management Panel to a more accessible area of the cockpit. In their present location (on the aft console), operation of the panels takes the pilot's vision "inside" the cockpit for too long and also takes one or both hands too far off either the cyclic and/or collective flight controls.

Mirror Imaging

There continues to be concern over the impact of mirror imaged versus identical cockpit configurations of primary flight displays. The mirror imaged display was prompted by the desire to have the radar altimeter occupy the outboard location of the forward console. After interviewing crew members, it is easy to understand the rationale behind this move. The radar altimeter is the primary instrument of interest in the cross-check during hovers and water operations. At these times crew members are constantly cross-checking the altimeter and looking outside to visually check altitude clearance. Consequently, it is necessary to have the radar altimeter in a location that optimizes the pilots visual scan time during high workload hover and water operations. Crew members unanimously prefer having the radar altimeter mirror imaged.

Unfortunately, this new configuration has prompted concerns by the Instrument Flight Center (IFC) at Randolph AFB, TX. The problem, as stated by Major Paul Caferrralla at the IFC, is not the physical location of the radar altimeter but that the change in configuration has caused the other primary flight displays to be displaced from the standard 'T' configuration on the right side of the cockpit. The IFC standard requires identical configuration for primary flight displays in all aircraft. A standard configuration eliminates transfer of training effects and helps to ensure that the pilots always know the location of primary instrument flight displays regardless of the aircraft platform. The standard configuration is Airspeed, Attitude, Barometric Altimeter Indicators for the horizontal axis of the "T" configuration. The right seat of the MH-60G GPS/NU is reversed with the order being; Barometric Altimeter, Attitude, Airspeed.

Major Caferralla also stated that the violation of the standard configuration can be worked around if the same information is displayed in the standard

configuration on the Heads Down Display (HDD). Unfortunately, this is not the case on the HDD in the MH-60G because there is no barometric altitude display.

A recommended solution to this dilemma is to perform a controlled experiment to determine the effects of mirror imaged versus identical cockpit displays. An extensive literature search revealed a lack of empirical data on mirror imaged versus identical cockpit display configurations. A thorough investigation would include (1) Tracking eye scan patterns in a simulator to provide information on where pilots look and (2) Conducting laboratory tests which measure the response time of crew members asked to report radar altitude readings as quickly as possible from mirror imaged and identical instrument configurations. This is the only way to provide a definitive answer to the question of mirror imaged versus identical cockpit configurations. The results of these studies could then be used to determine the optimal location for the radar altimeter. However, it's impact on the standard "T" configuration issue is questionable. In the meantime, the best way to comply with the IFC would be to display barometric altitude in the standard configuration on the HDD.

Voice Activated Warning System (VAWS)

Research has shown that pilots respond more quickly to voice activated warnings as opposed to visual or pure tone warnings, particularly under conditions of high task loading (Boff & Lincoln, 1988). Effective warning systems must be reliable and instances of false alarms must be minimal to ensure crew confidence. Pilots stated that the VAWS is reliable and confidence in the system is high. Pilots also stated that the system is frequently activated during training and they have to "get in the habit of turning it off." It must be stressed that training on the response to VAWS must be a deliberate, conscious act, NOT an automatic response or "habit." Crew members must be diligent in setting the altitude warning level so that instances where the warning is activated inappropriately are minimized. It is imperative that pilots not be negligent in this responsibility because it could lead to a potentially dangerous behavior pattern (i.e. getting in the habit of turning it off or tuning out the warning). A proposed change to the cyclic recommends putting the VAWS reset switch on the cyclic. If this does occur, it is imperative that the training previously suggested be adhered to. Having the reset button on the cyclic will make it very easy to get in the "habit" of automatically resetting the system.

Cyclic & Collective Grips

Late in 1992 a proposal to change the cyclic and collective grips prompted a number of human factors concerns. Armstrong Laboratory continues to stand by the recommendations previously made on this issue (see Appendix D). However, the potential benefit of incorporating more functions on the cyclic and collective are well recognized. Incorporating more functionality will significantly reduce the amount of time that pilots currently spend with their heads down in the cockpit.

Easy access to functions that are used frequently or during critical phases of flight will alleviate the time consuming and potentially dangerous, finger light searches that pilots currently contend with.

Nonetheless, it must be stressed that an intelligent, systematic, thorough, multi-disciplinary approach that incorporates an extensive training plan be undertaken to determine the optimal size, shape, functionality and switchology for the proposed cyclic and collective grips. An experienced team of pilots should develop a prioritized list of functions based on criticality and frequency of use. Anthropologists should be consulted on the design of the grip to make sure it fits the pilot populations hand size and that all switches are easy to reach and operate. Human factors engineers should be consulted to ensure that the assignment of functions to switches complies with the list of priorities and human factors principles. It is also important to avoid changes that strongly conflict with the current configuration.

To overcome the effects of negative transfer of training, it is important that a switch that is currently used frequently isn't reallocated to a low frequency, highly critical task. (The Army experienced definite negative transfer problems when they changed the go around switch to mini-guns and the cargo hook switch to rockets.) Finally, it must be stressed that the most effective way to facilitate the transition to the new grips is to establish a thorough grip familiarization and training program. It is still the position of Armstrong Laboratory to approach this redesign carefully and with the aid of human factors engineers and anthropologists.

Training

Whenever new systems are introduced into a work environment, training programs must exist to empower users with the knowledge and operation of all of the capabilities of the system. These training programs will insure proficiency and increase system and operator effectiveness. Oftentimes enhancements are made to systems that are rarely utilized because the operator is not aware of the capabilities available to them. A classic example of this problem is word processors. Word processors today have enormous power and provide tremendous capabilities that go unutilized because users are not trained on the operation of options that are available to them. In the case of an aircraft system, most upgrades occur because of a recognized deficiency or the advent of a new technology that is designed to improve efficiency. In either case, if pilots are not trained to effectively utilize these systems, a great deal of resources are not only wasted , but lives can be lost as well. Resource waste and loss of life can both be prevented by training on the existing, high fidelity MH-60G cockpit simulators located at Kirtland AFB, Albuquerque, New Mexico. Periodic simulator training on high risk, high workload maneuvers should be instituted as policy.

The questionnaires circulated in the squadron asked pilots first if there was a task that they thought needed further training for and second, what they thought that training should be. The results of the questionnaire are presented in Table 5

below. Several people identified the new GPS navigation system as one that could benefit from additional training.

Table 5 . Training Requirements & Suggested Training

Tasks that Require More Training	Suggested Training
- Joint dissimilar & multi-ship (3 or more) formation	More dissimilar & multi-ship training
- GPS/NU mobile way point navigation	Ground training on GPS navigation procedures
- GPS/NU aircraft familiarization	Blind cockpit & simulator training
- FLIR hover	FLIR training
- FLIR/VSDS usage	FLIR training & simulator training
- Night water and shipboard operations	Simulator training

Access

There were two major problems with regards to the accessibility of specific controls and/or displays. These were 1) the location of radio controls and 2) the location of certain instruments on the aft console. Concerning the radios, communications tasks occur several times during a mission and as a result, radio frequencies must be changed often. The radio controls are dispersed throughout the cockpit, often in inaccessible locations that require pilots to assume awkward, contorted postures in order to operate the radios. This also forces the pilot and/or copilot to bring their attention "inside" the cockpit to search for radio control heads when their attention is most needed "outside" the cockpit. The communications should be integrated through the CDU to alleviate searching for controls and to provide a central location for this task to be performed. In addition, the CDU can be preprogrammed so that only a single button push would be required to change frequencies when desired. This would again save time and require less focusing attention "inside" the cockpit.

The Army version of the MH-60G and the MH-53J are both equipped with an integrated communications system and one Army helicopter pilot we interviewed said the system was excellent. There are ten radio systems onboard the MH-60G, all of which could be integrated into one system. These ten radio systems are shown in

Table 5 below. Integration of the radios would free up space toward the front portion of the aft console and reduce flying weight by approximately 100 lbs. The freed up space could be used for other displays/controls presently located on the back portion of the aft console such as the FLIR, SCU and Fuel Management Panel.

Table 6. Candidate Radio Systems for Single Unit Integration.

ARC-186 VHF Radio	ARC-199 HF Radio
KY-58 Secure Voice	KY-75 Secure Voice
ARN-123 VOR/ILS	APX-100 Transponder
ARN-118 TACAN	KIT-1A IFF
ARC-187 SATCOM	AN/ARS-6 LARS

Most of the displays/controls located on the aft console are inaccessible without having to make awkward, backward reaches to operate the controls or view the displays. Any frequently used control/ display should be placed as far forward on the lower or aft consoles as possible. The aft console should only contain controls/displays that are seldom used and are of a non-critical nature.

To ensure and maximize crew performance and flight safety it is imperative that the most frequently used and most critical displays and controls be accessed quickly and easily. We have compiled a list of such MH-60G displays/controls (Table 6 & 7 below). Should there be a decision to insert new avionics systems (AHHS) into the cockpit, the displays/controls listed in table 6 and 7 should be considered before any location changes are made. The controls listed in table 7 are considered emergency controls and should be kept close enough to the pilots that each control can be accessed with locked inertial reels.

Table 7. High Frequency of Use Controls/Displays by Console.

Console	Control/Display
Front	Radar Altimeter
	VSI/HSI Mode Select
	CIS Mode Select
	NAV Mode Select
	Heading and Course Select
Lower	CDU
	ICS
	All COM and NAV
	VAWS (Voice Activated Warning System)
	FLIR Stick
	Transponder
	PLS

Table 7. (cont'd)

Console	Control/Display
Upper	Windscreen Wipers Lights (signaling) Cargo Hook
Aft	Fuel Management Panel Cyber Radio (KY58)

Table 8. Emergency/Locked Inertial Reels Controls

Controls
Throttles
Fuel Boost Pumps
APU Fire Extinguishers
AFCS Panel
Master Cutoff Switch
All Fire Extinguisher T-handles
Transponder (IFF Emergency)
ICS panel
External Fuel/Rocket Jettison
Radio Guard Switch (emergency broadcast)
Override Stabilator

The obvious solution to the problem is to integrate the radios with the CMS-80 and access them through the CDU. Another solution which is in place in the Army MH-47E is to integrate the communications and have a control on the cyclic to select radios with a small display located on the forward console to indicate the selected radio. Integrating the communication systems would not only alleviate the problems associated with radio access, but also free up considerable space on the center and aft consoles. Reconfigured lower and aft consoles with the radios integrated into the CDU are shown in Figures 20 & 21. This reconfiguration would drastically reduce the size of the aft console. The reconfigured aft console would also provide an alternate egress route for pilots and give the flight engineer visual access to controls and displays in the cockpit.

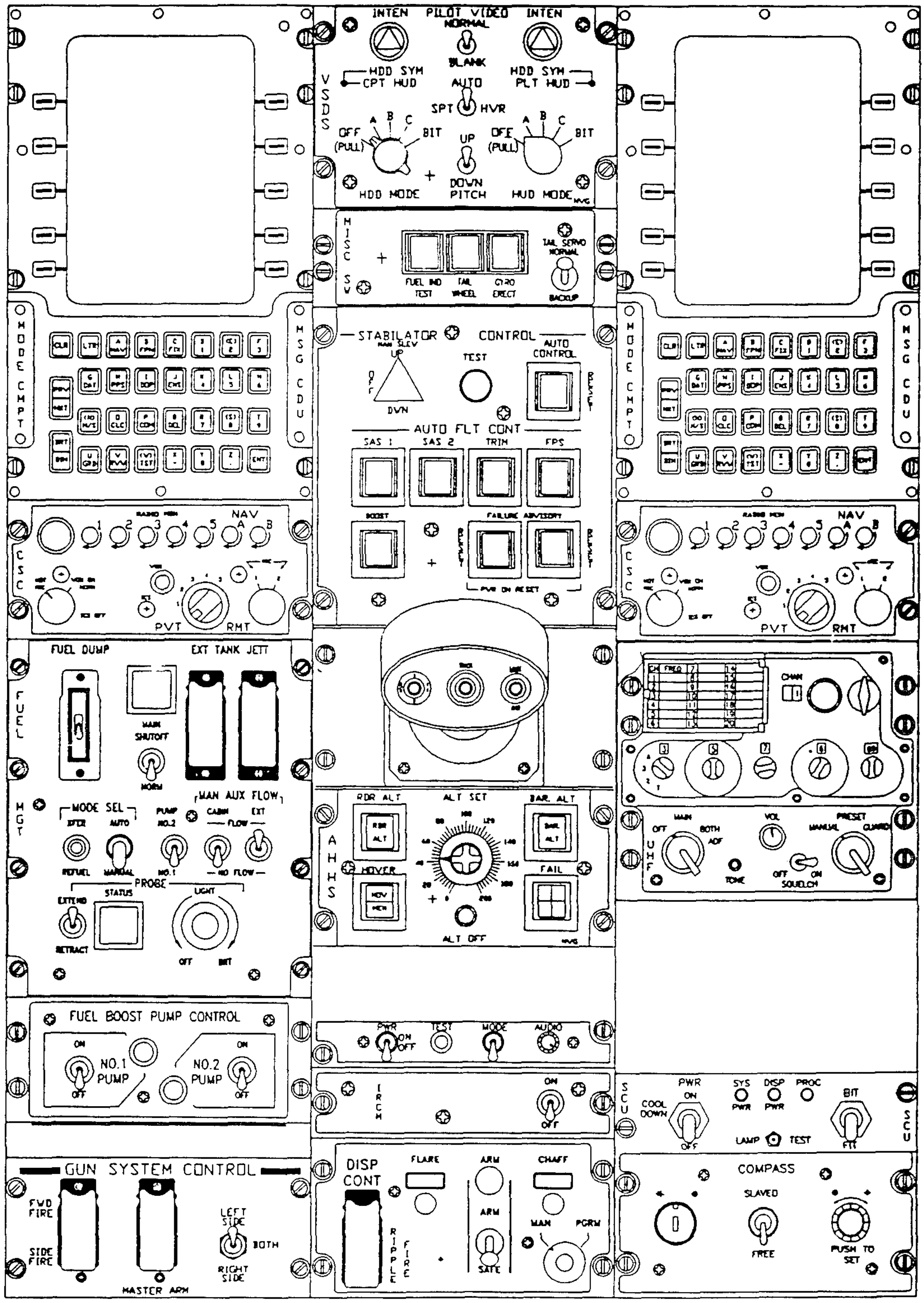

Figure 20. Reconfigured Lower Console with Radios Integrated into the CDU.

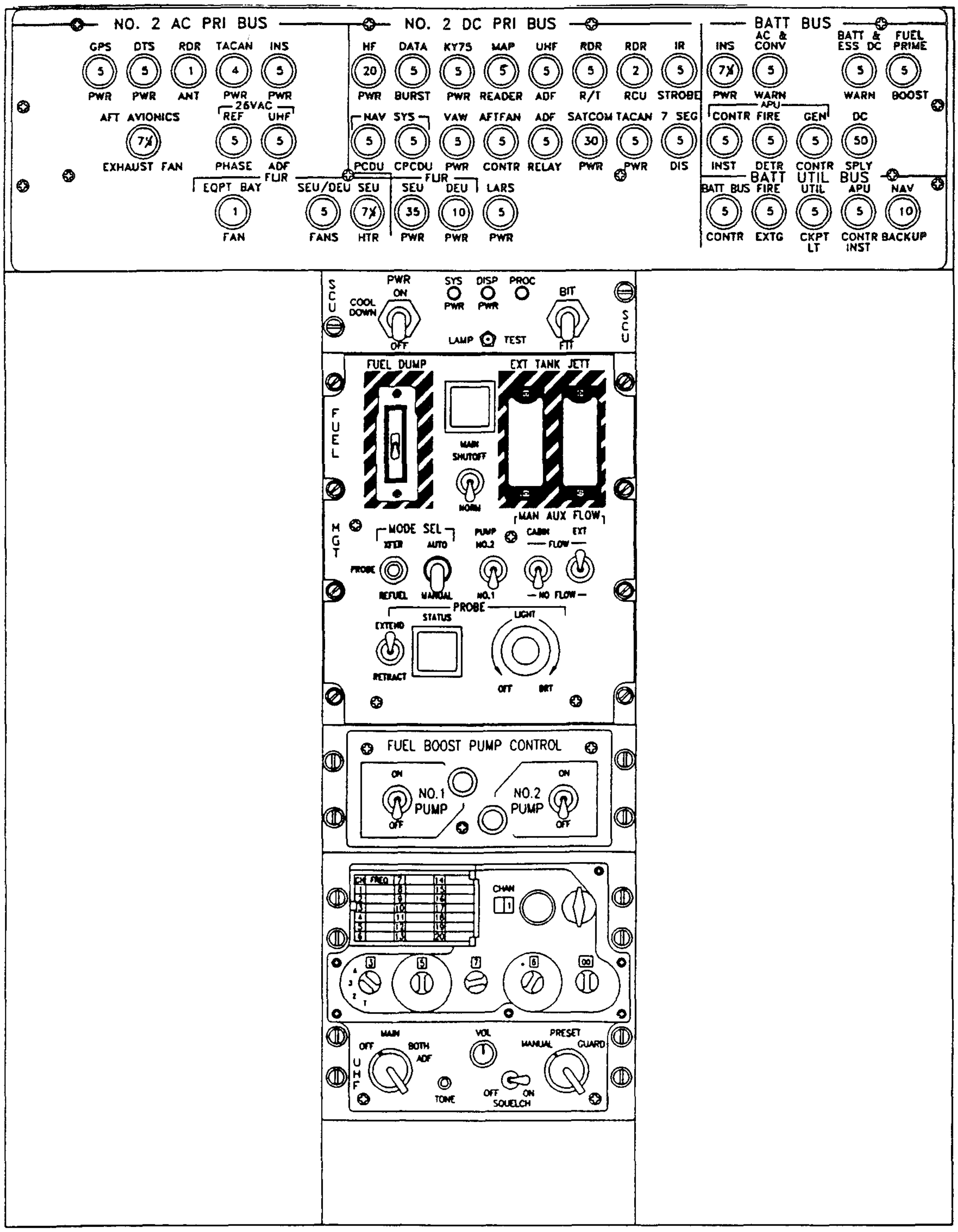

Figure 21. Reconfigured Aft Console with Radios Integrated Through the CDU.

Lighting

The MH-60G mission requires a large amount of night operations. Night vision goggles (NVGs) are used extensively during these operations because of the mission requirement to operate under the cover of darkness. Therefore, no interior or exterior lighting can be used. However, the MH-60G was never outfitted with an NVG compatible interior lighting system. Instead, the crew flies its night missions with no interior lighting at all. This requires the pilot or copilot to use a finger light to search for and operate desired subsystems. The result is an inordinate amount of time spent "inside" the cockpit which decreases mission performance and flight safety. The questionnaire ratings reflect this and the pilots unanimously agreed in the individual interviews that the cockpit needs to be made NVG compatible in a manner other than just turning the panel lights off. NVG compatible lighting is a basic requirement for night operations and should, therefore, be installed in this aircraft.

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Appendix A: High Workload Task Concept Maps and Map Outlines

Navigation Concept Map

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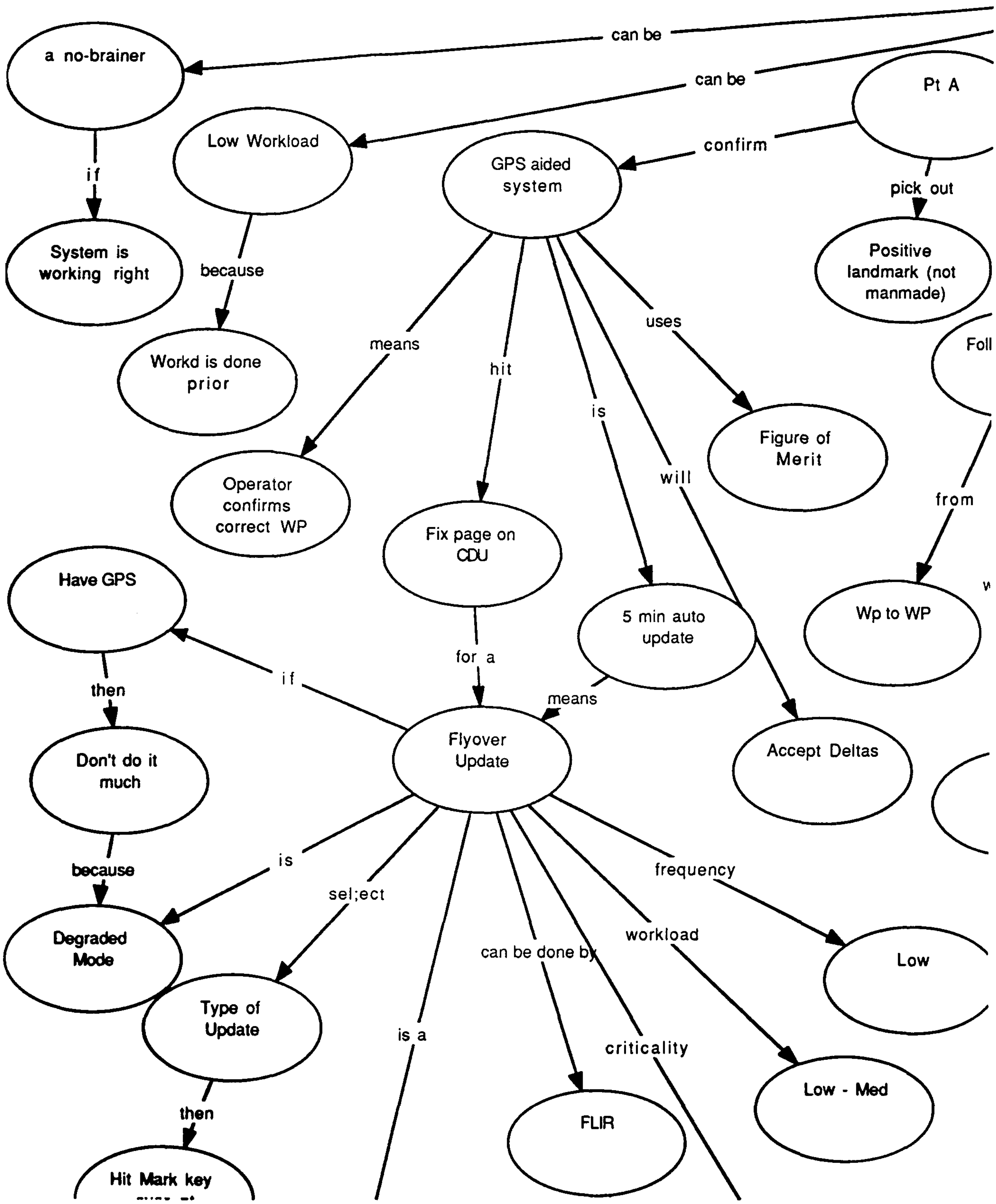
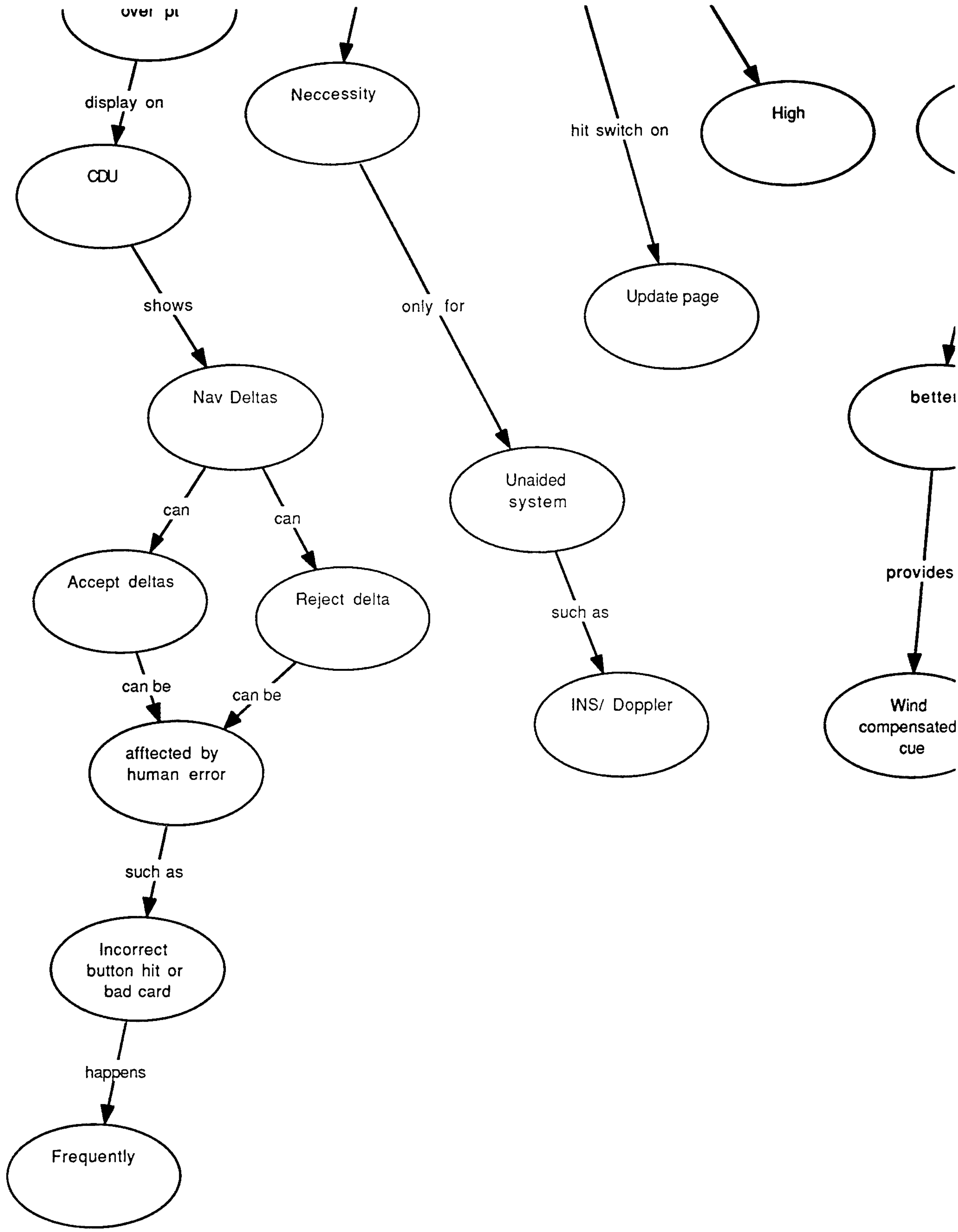
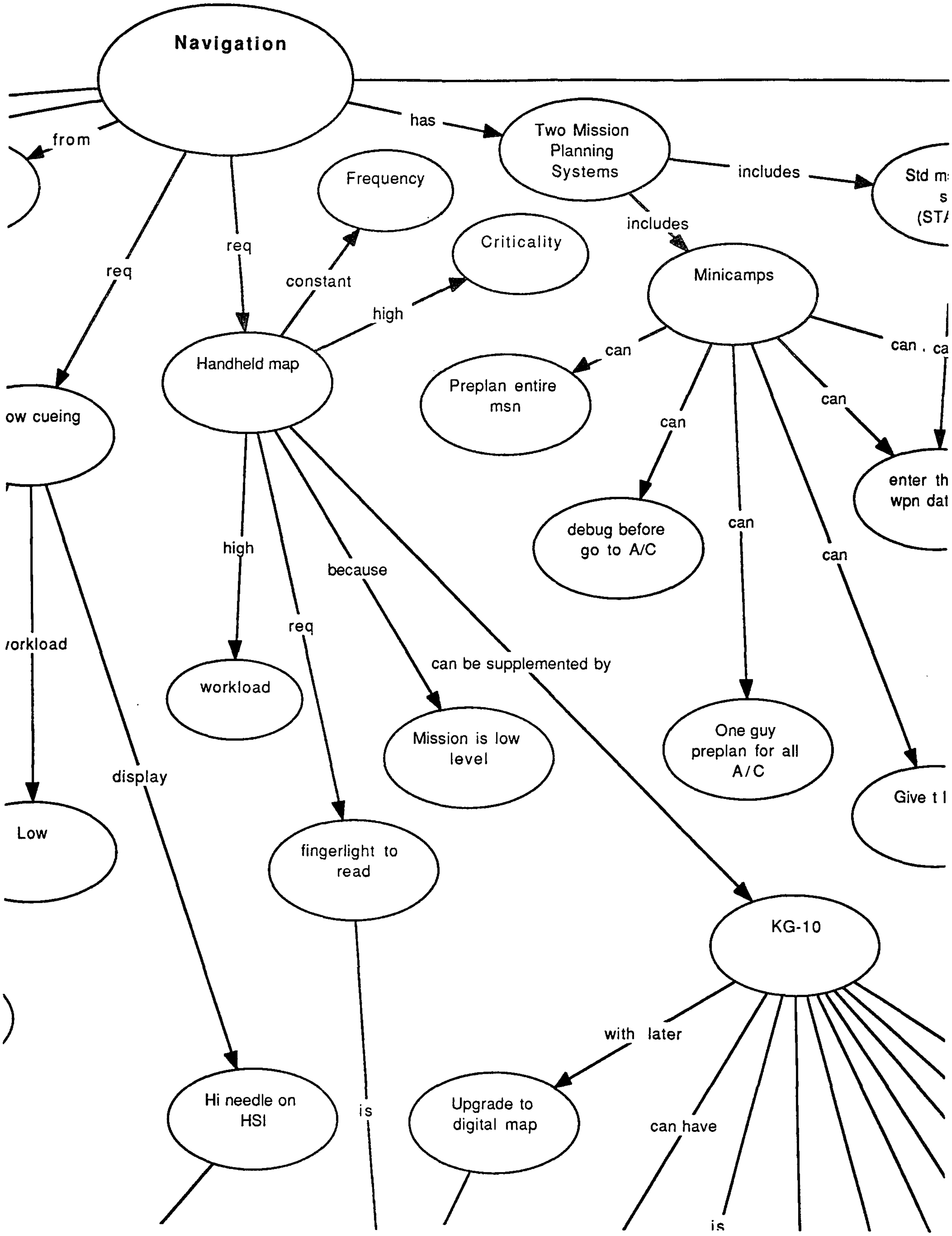


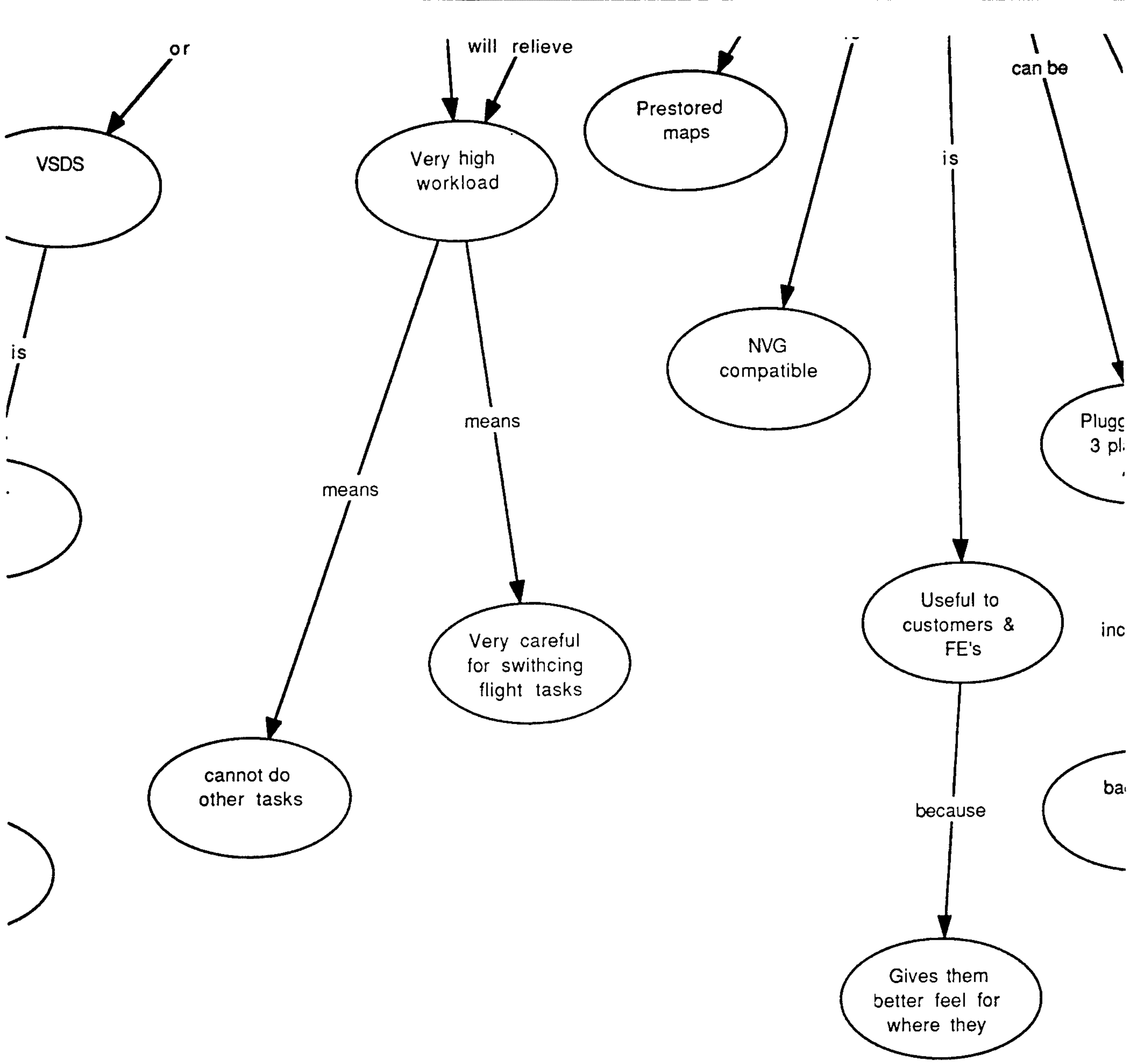
can be
can be
a no-brainer
if
System is working right
Low Workload
because
Workd is done prior
confirm
Pt A
pick out
Positive landmark (not manmade)
GPS aided system
means
Operator confirms correct WP
hit
Fix page on CDU
is
5 min auto update
will
Accept Deltas
uses
Figure of Merit
Foll
from
Wp to WP
Have GPS
then
Don't do it much
because
Degraded Mode
if
for a
means
Flyover Update
is
sel;ect
Type of Update
then
Hit Mark key
is a
can be done by
FLIR
criticality
workload
Low - Med
frequency
Low

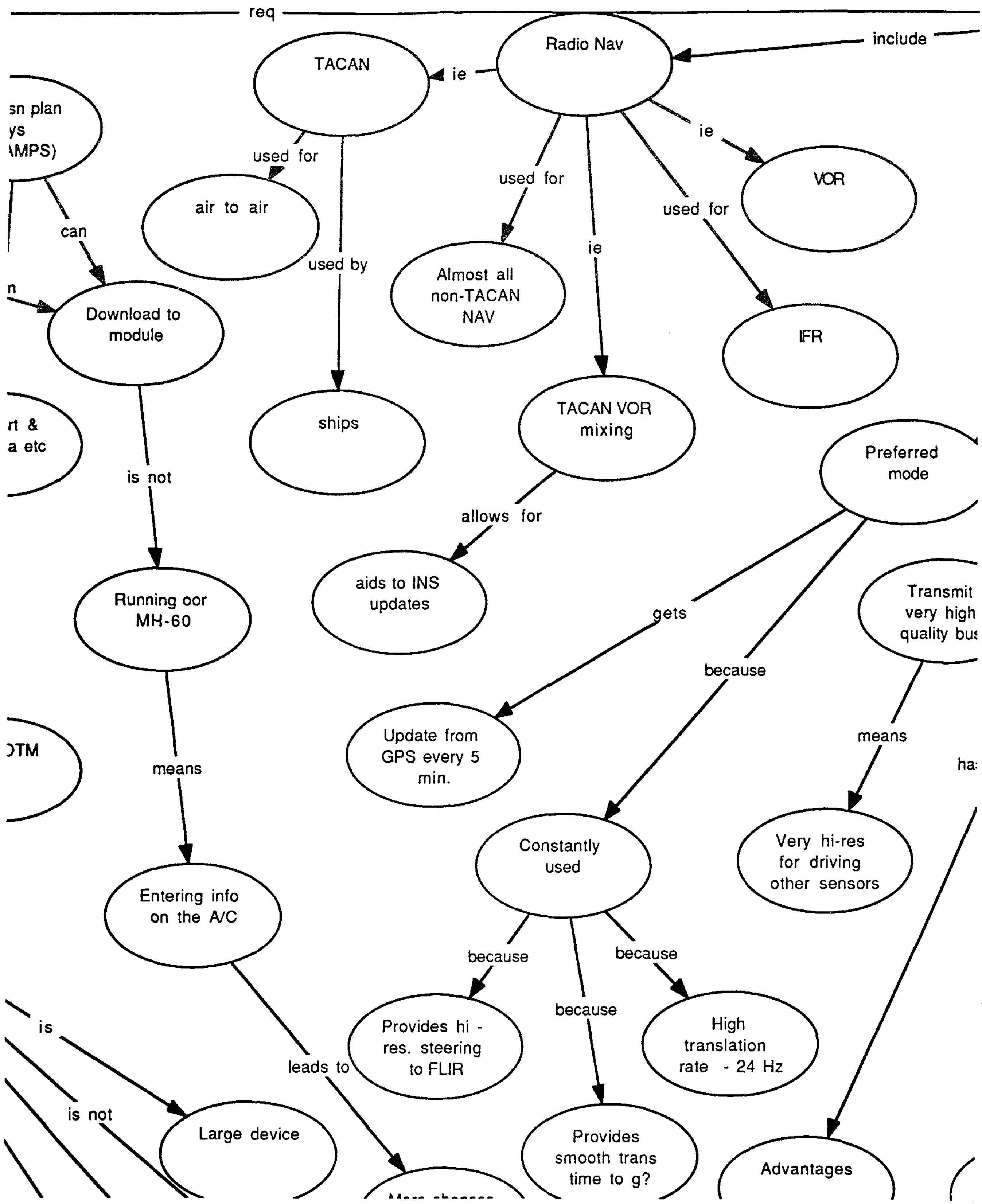


over pt
display on
CDU
shows
Nav Deltas
can
can
Accept deltas
Reject delta
can be
can be
afftected by human error
such as
Incorrect button hit or bad card
happens
Frequently
Neccessity
only for
Unaided system
such as
INS/ Doppler
hit switch on
Update page
High
bette
provides
Wind compensated cue

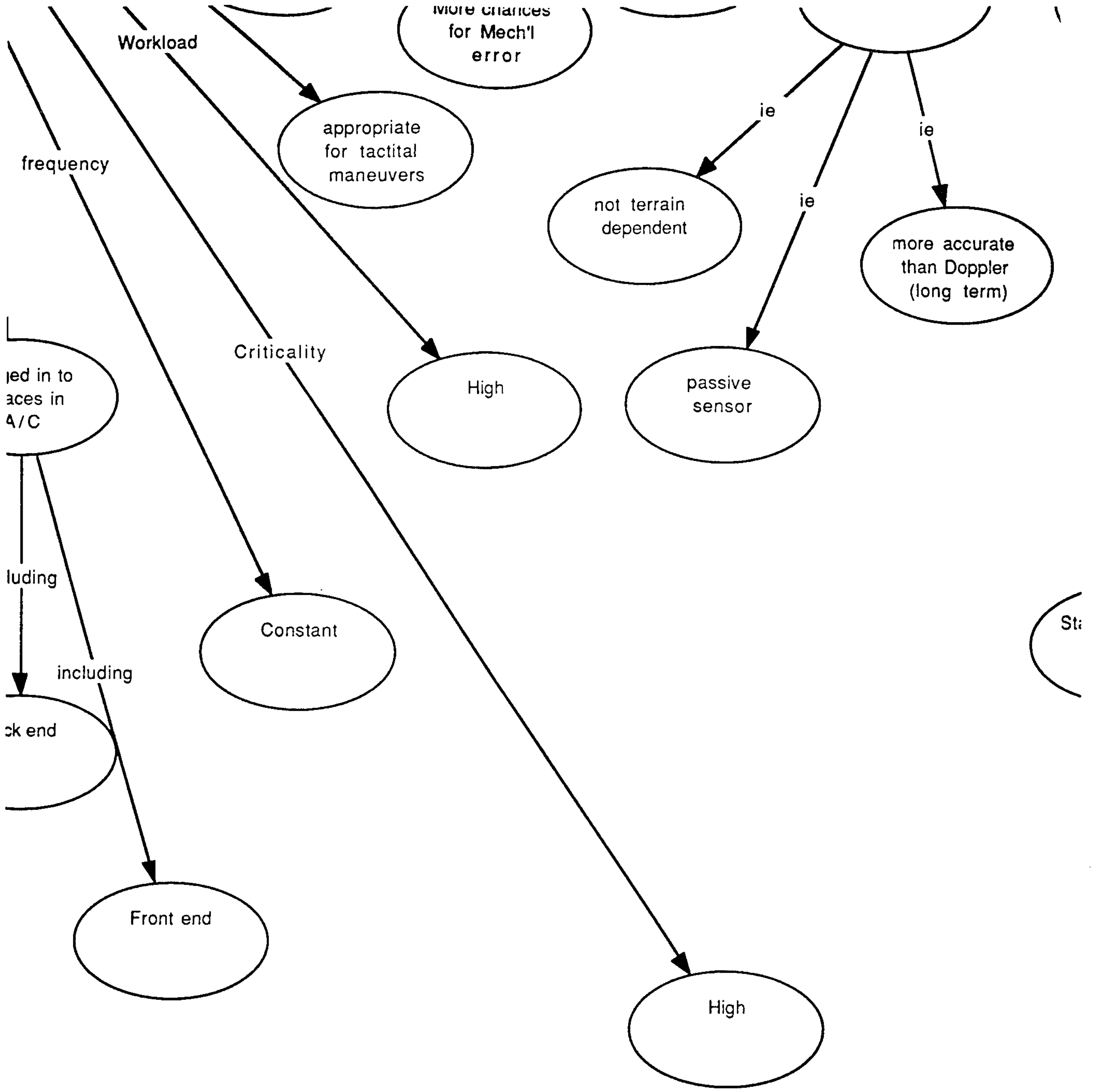


Navigation
from
has
Two Mission Planning Systems
includes
Std m s (ST
includes
Frequency
Criticality
Minicamps
req
req
constant
high
can
can . ca
Handheld map
Preplan entire msn
ow cueing
can
can
enter th wpn dat
debug before go to A/C
can
can
high
because
orkload
req
can be supplemented by
workload
Mission is low level
One guy preplan for all A/C
display
Give t l
Low
fingerlight to read
KG-10
with later
Hi needle on HSI
is
Upgrade to digital map
can have
is

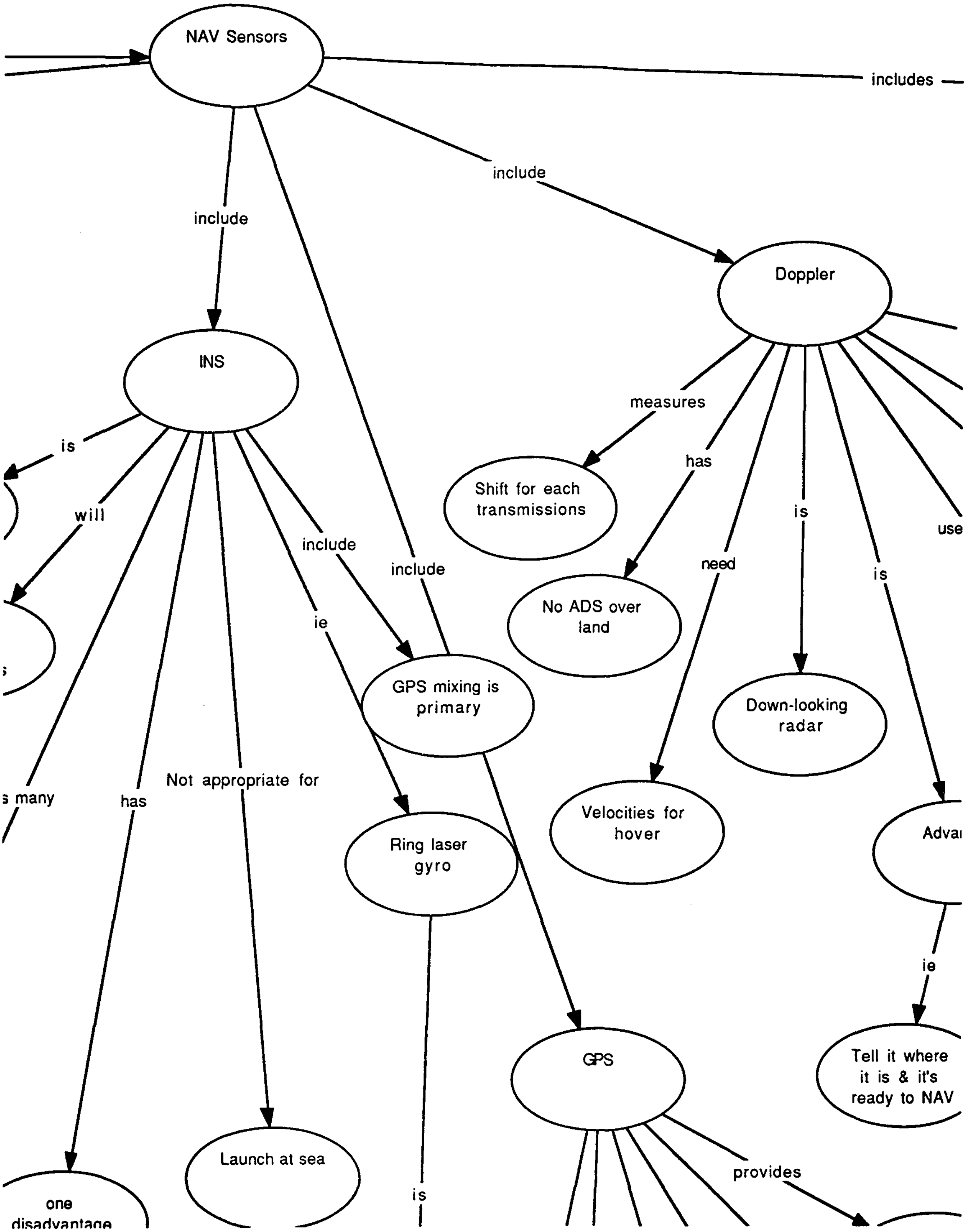

or
will relieve
Prestored maps
can be
VSDS
Very high workload
is
is
NVG compatible
means
Plugg
3 pl
means
Useful to customers & FE's
inc
Very careful for swithcing flight tasks
cannot do other tasks
ba
because
Gives them better feel for where they

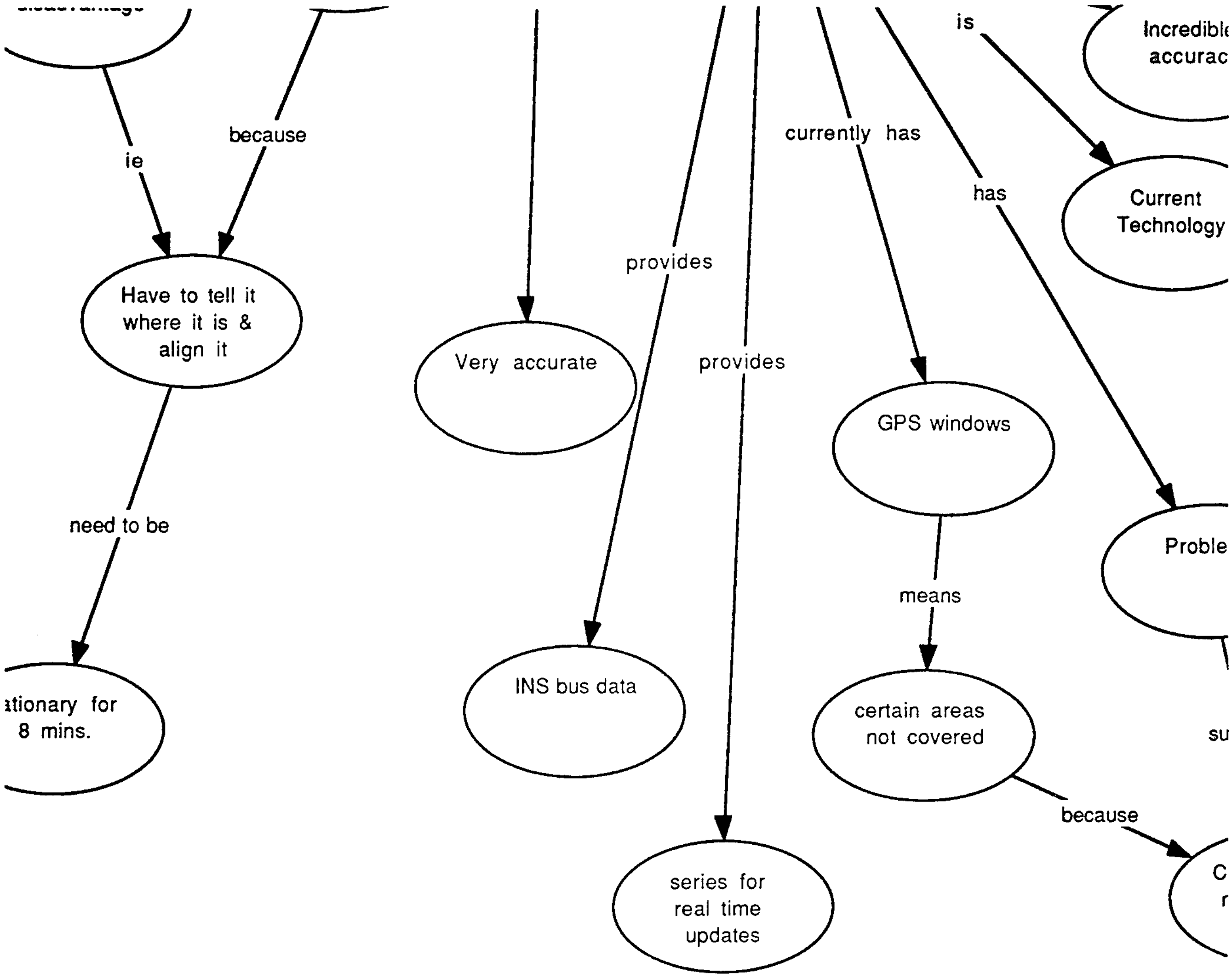


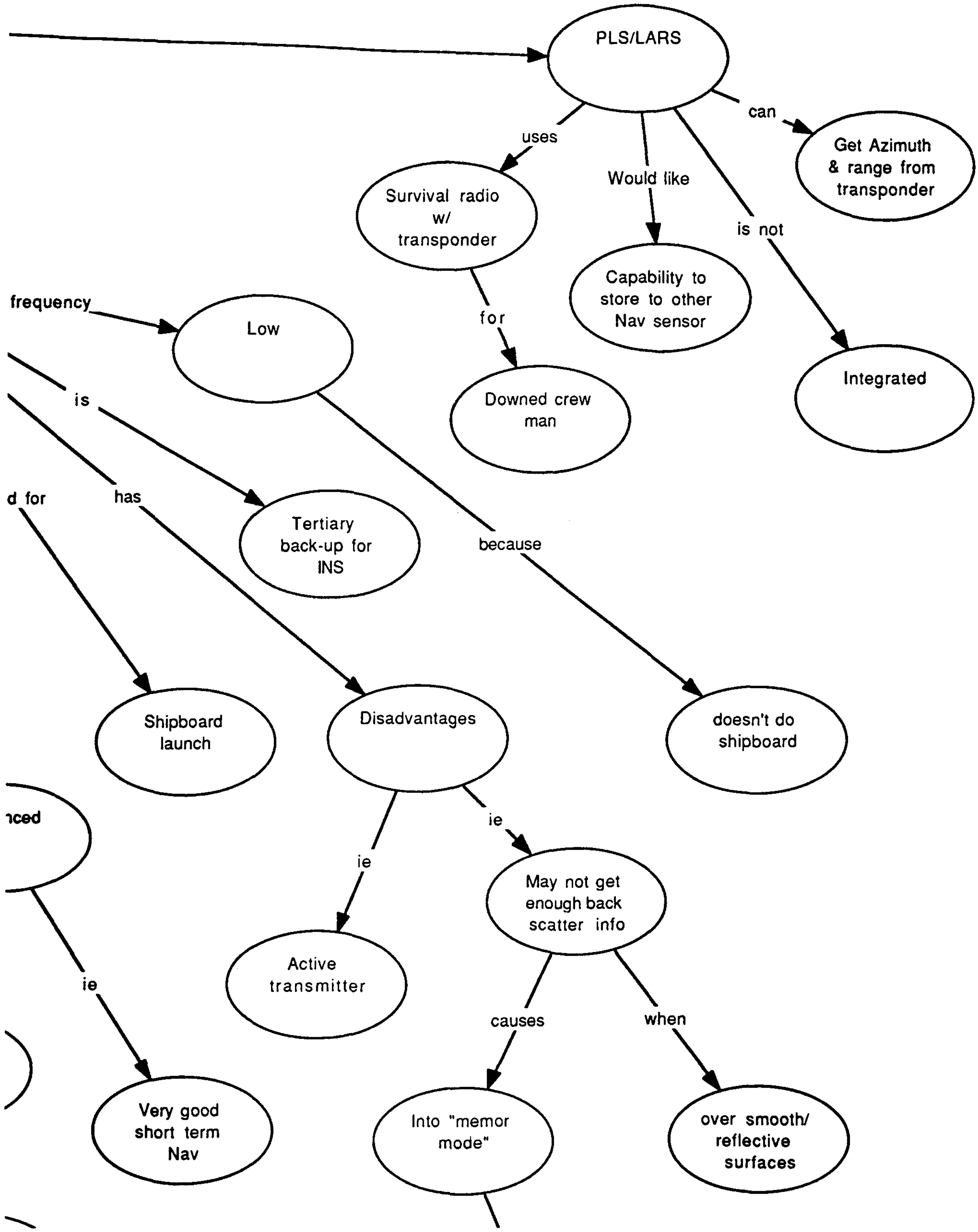
req
Radio Nav
include
TACAN
ie
sn plan
ys
\MPS)
used for
air to air
used by
ships
used for
Almost all non-TACAN NAV
ie
VOR
used for
IFR
ie
TACAN VOR mixing
can
n
Download to module
rt &
a etc
is not
Running oor MH-60
allows for
aids to INS updates
Preferred mode
gets
Transmit very high quality bu
because
Update from GPS every 5 min.
means
Very hi-res for driving other sensors
)TM
means
Entering info on the A/C
Constantly used
because
because
because
Provides hi - res. steering to FLIR
High translation rate - 24 Hz
Provides smooth trans time to g?
is
is not
leads to
Large device
Advantages

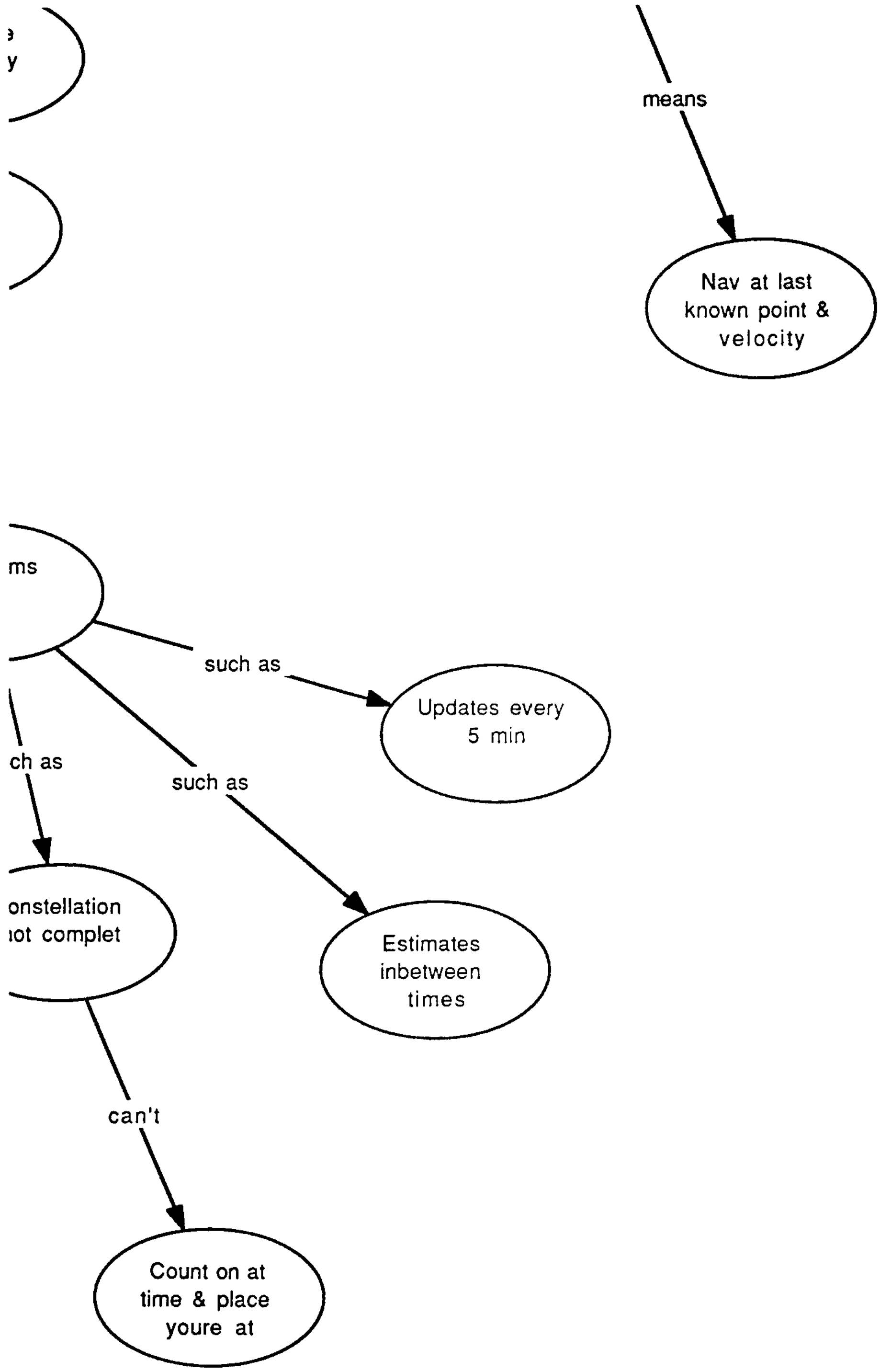


for Mech'l error
Workload
appropriate for tactital maneuvers
frequency
ie
not terrain dependent
ie
ie
more accurate than Doppler (long term)
Criticality
High
passive sensor
Constant
including
Front end
High


NAV Sensors
includes
include
include
Doppler
INS
is
will
measures
has
Shift for each transmissions
is
use
include
include
need
No ADS over land
ie
is
GPS mixing is primary
Down-looking radar
s many
has
Not appropriate for
Velocities for hover
Ring laser gyro
Advai
ie
Tell it where it is & it's ready to NAV
GPS
Launch at sea
provides
is
one disadvantage


ie
because
Have to tell it where it is & align it
need to be
ationary for 8 mins.
Very accurate
provides
INS bus data
provides
series for real time updates
currently has
GPS windows
means
certain areas not covered
because
has
is
Incredible accurac
Current Technology
Proble
su


PLS/LARS
uses
can
Would like
is not
Get Azimuth & range from transponder
Survival radio w/ transponder
Capability to store to other Nav sensor
Integrated
frequency
Low
for
Downed crew man
is
Tertiary back-up for INS
d for
has
because
Shipboard launch
Disadvantages
doesn't do shipboard
ıced
ie
ie
May not get enough back scatter info
Active transmitter
ie
causes
when
Very good short term Nav
Into "memor mode"
over smooth/ reflective surfaces



e
y
means
Nav at last known point & velocity
ms
such as
Updates every 5 min
ch as
such as
onstellation
iot complet
Estimates inbetween times
can't
Count on at time & place youre at

Navigation Map Outline

- Navigation can be a no-brainer.
  - a no-brainer if System is working right.
- Navigation can be Low Workload.
  - Low Workload because Workd is done prior.
- Navigation from Pt A.
  - Pt A confirm GPS aided system.
    - GPS aided system means Operator confirms correct WP.
    - GPS aided system hit Fix page on CDU.
      - Fix page on CDU for a Flyover Update.
        - Flyover Update if Have GPS.
          - Have GPS then Don't do it much.
            - Don't do it much because Degraded Mode.
        - Flyover Update is Degraded Mode.
        - Flyover Update sel;ect Type of Update.
          - Type of Update then Hit Mark key over pt.
            - Hit Mark key over pt display on CDU.
              - CDU shows Nav Deltas.
                - Nav Deltas can Accept deltas.
                  - Accept deltas can be affected by human error.
                    - affected by human error such as Incorrect button hit or bad card.
                      - Incorrect button hit or bad card happens Frequently.
                - Nav Deltas can Reject delta.
                  - Reject delta can be afftected by human error.
        - Flyover Update is a Neccessity.
          - Neccessity only for Unaided system.
            - Unaided system such as INS/ Doppler.
        - Flyover Update can be done by FLIR.
          - FLIR hit switch on Update page.
        - Flyover Update frequency Low.
        - Flyover Update criticality High.
        - Flyover Update workload Low - Med.
    - GPS aided system is 5 min auto update.
      - 5 min auto update means Flyover Update.
    - GPS aided system will Accept Deltas.
    - GPS aided system uses Figure of Merit.
  - Pt A pick out Positive landmark (not manmade).
- Navigation req Follow cueing.
  - Follow cueing from Wp to WP.
  - Follow cueing display Hi needle on HSI.
    - Hi needle on HSI or VSDS.
    - VSDS is better.
      - better provides Wind compensated cue.

Follow cueing workload Low.
Navigation req Handheld map.
Handheld map high workload.
Handheld map high Criticality.
Handheld map constant Frequency.
Handheld map because Mission is low level.
Handheld map req fingerlight to read.
fingerlight to read is Very high workload.
Very high workload means cannot do other tasks.
Very high workload means Very careful for swithcing flight tasks.
Handheld map can be supplemented by KG-10.
KG-10 Criticality High.
KG-10 is Large device.
KG-10 can have Prestored maps.
KG-10 is NVG compatible.
KG-10 is Useful to customers & FE's.
Useful to customers & FE's because Gives them better feel for where they are and where they are going.
KG-10 is not appropriate for tactital maneuvers.
KG-10 with later Upgrade to digital map.
Upgrade to digital map will relieve Very high workload.
KG-10 can be Plugged in to 3 places in A/C.
Plugged in to 3 places in A/C including back end.
Plugged in to 3 places in A/C including Front end.
KG-10 frequency Constant.
KG-10 Workload High.Navigation has Two Mission Planning Systems.
Two Mission Planning Systems includes Minicamps.
Minicamps can Preplan entire msn.
Minicamps can debug before go to A/C.
Minicamps can One guy preplan for all A/C.
Minicamps can Give t DTM.
Minicamps can Download to module.
Download to module is not Running oor MH-60.
Running oor MH-60 means Entering info on the A/C.
Entering info on the A/C leads to More chances for Mech'l error.
Minicamps can enter thrt & wpn data etc.
Two Mission Planning Systems includes Std msn plan sys (STAMPS).
Std msn plan sys (STAMPS) can Download to module.
Std msn plan sys (STAMPS) can enter thrt & wpn data etc.
Navigation req NAV Sensors.
NAV Sensors include Radio Nav.
Radio Nav ie TACAN.
TACAN used for air to air.
TACAN used by ships.
Radio Nav ie TACAN VOR mixing.

TACAN VOR mixing allows for aids to INS updates.
Radio Nav used for IFR.
Radio Nav ie VOR.
Radio Nav used for Almost all non-TACAN NAV.
NAV Sensors include INS.
INS is Preferred mode.
Preferred mode because Constantly used.
Constantly used because Provides hi - res. steering to FLIR.
Constantly used because Provides smooth trans time to g?.
Constantly used because High translation rate - 24 Hz.
Preferred mode gets Update from GPS every 5 min..
INS will Transmit very high quality bus data.
Transmit very high quality bus data means Very hi-res for driving other sensors.
INS has many Advantages.
Advantages ie not terrain dependent.
Advantages ie passive sensor.
Advantages ie more accurate than Doppler (long term).
INS has one disadvantage.
one disadvantage ie Have to tell it where it is & align it.
Have to tell it where it is & align it need to be Stationary for 8 mins.
INS Not appropriate for Launch at sea.
Launch at sea because Have to tell it where it is & align it.
INS include GPS mixing is primary.
INS ie Ring laser gyro.
Ring laser gyro is Very accurate.
NAV Sensors include GPS.
GPS provides INS bus data.
GPS provides series for real time updates.
GPS is Current Technology.
GPS currently has GPS windows.
GPS windows means certain areas not covered.
certain areas not covered because Constellation not complet.
GPS provides Incredible accuracy.
GPS has Problems.
Problems such as Updates every 5 min.
Problems such as Estimates inbetween times.
Problems such as Constellation not complete.
Constellation not complete can't Count on at time & place youre at.
NAV Sensors include Doppler.
Doppler measures Shift for each transmissions.
Doppler has No ADS over land.
Doppler need Velocities for hover.
Doppler is Down-looking radar.
Doppler is Advanced.
Advanced ie Tell it where it is & it's ready to NAV.

Advanced ie Very good short term Nav.
Doppler used for Shipboard launch.
Doppler has Disadvantages.
Disadvantages ie Active transmitter.
Disadvantages ie May not get enough back scatter info.
May not get enough back scatter info caus Into "memor mode".
Into "memor mode" means Nav at last known point & velocity.
May not get enough back scatter info when over smooth/ reflective surfaces.
Doppler is Tertiary back-up for INS.
Doppler frequency Low.
Low because doesn't do shipboard.
NAV Sensors includes PLS/LARS.
PLS/LARS uses Survival radio w/ transponder.
Survival radio w/ transponder for Downed crew man.
PLS/LARS Would like Capability to store to other Nav sensor.
PLS/LARS is not Integrated.
PLS/LARS can Get Azimuth & range from transponder.

Aerial Refueling Concept Map

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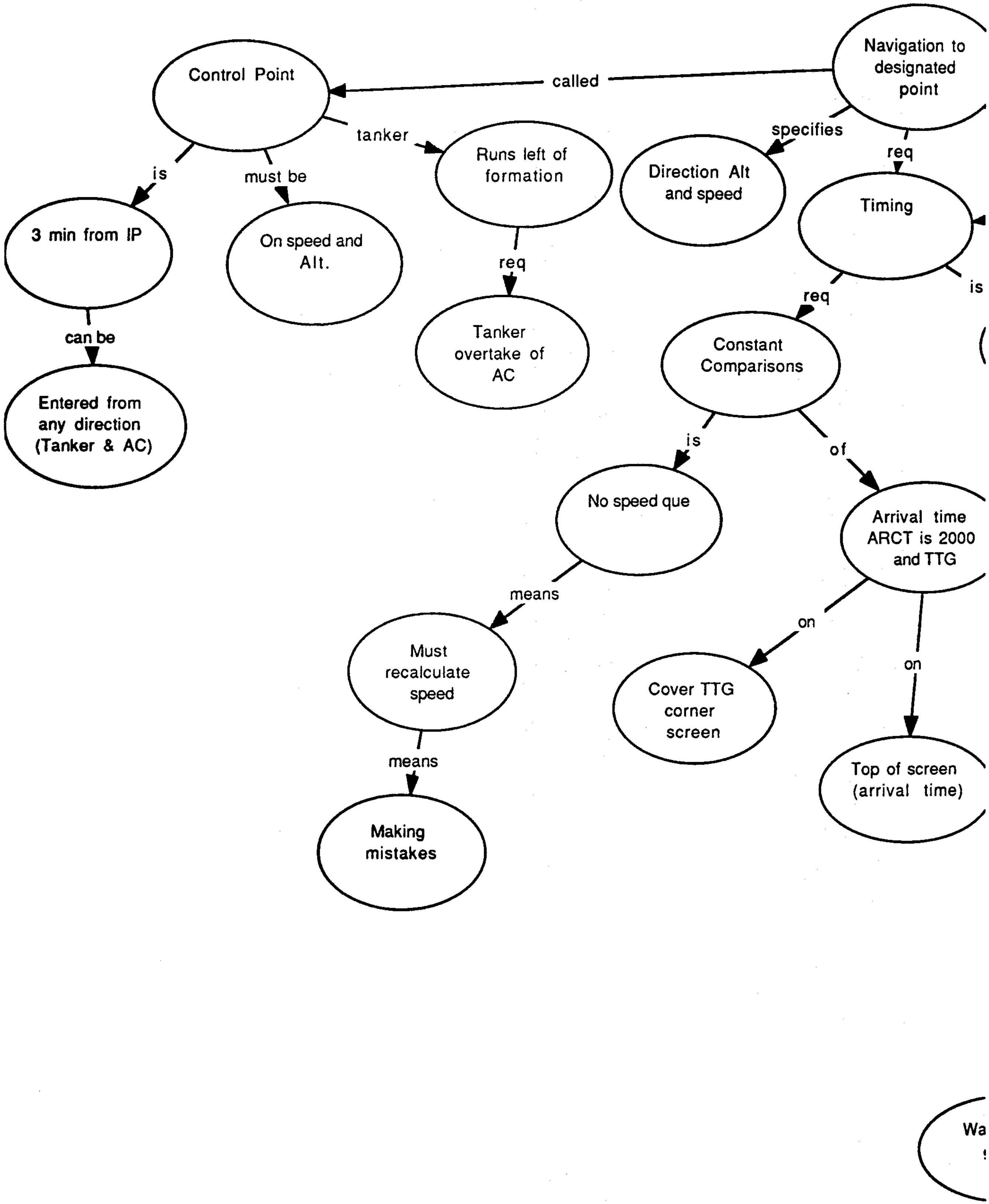
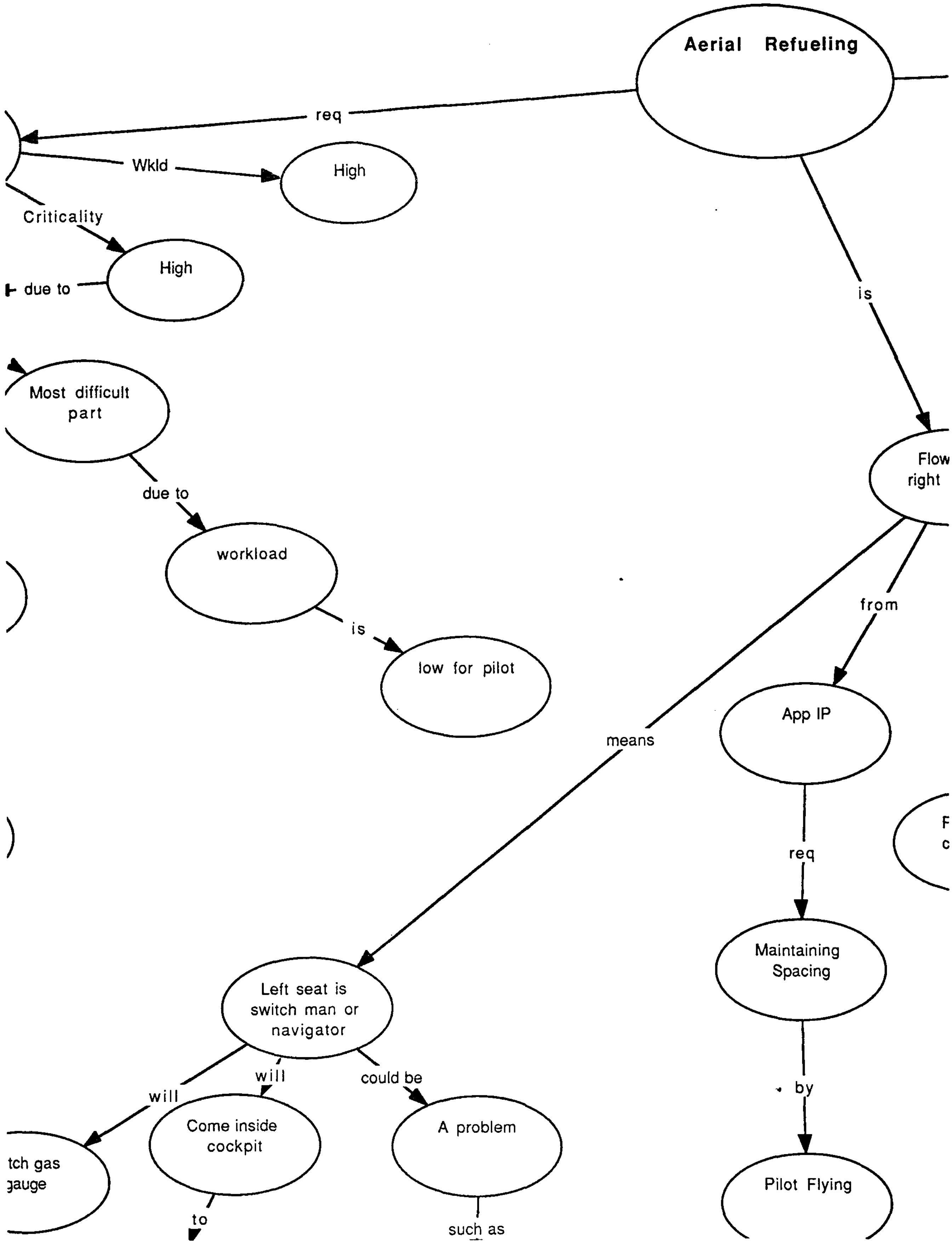
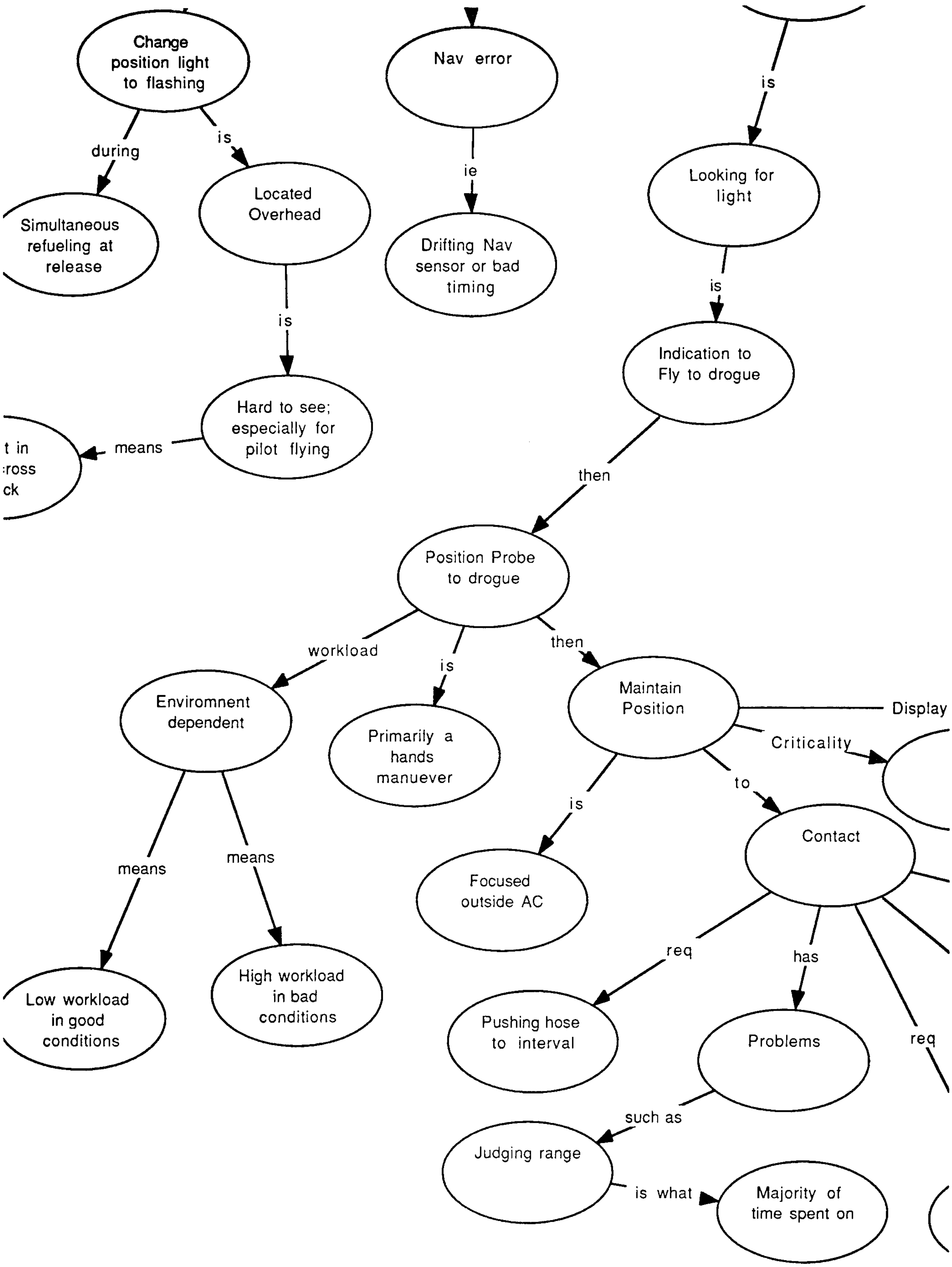
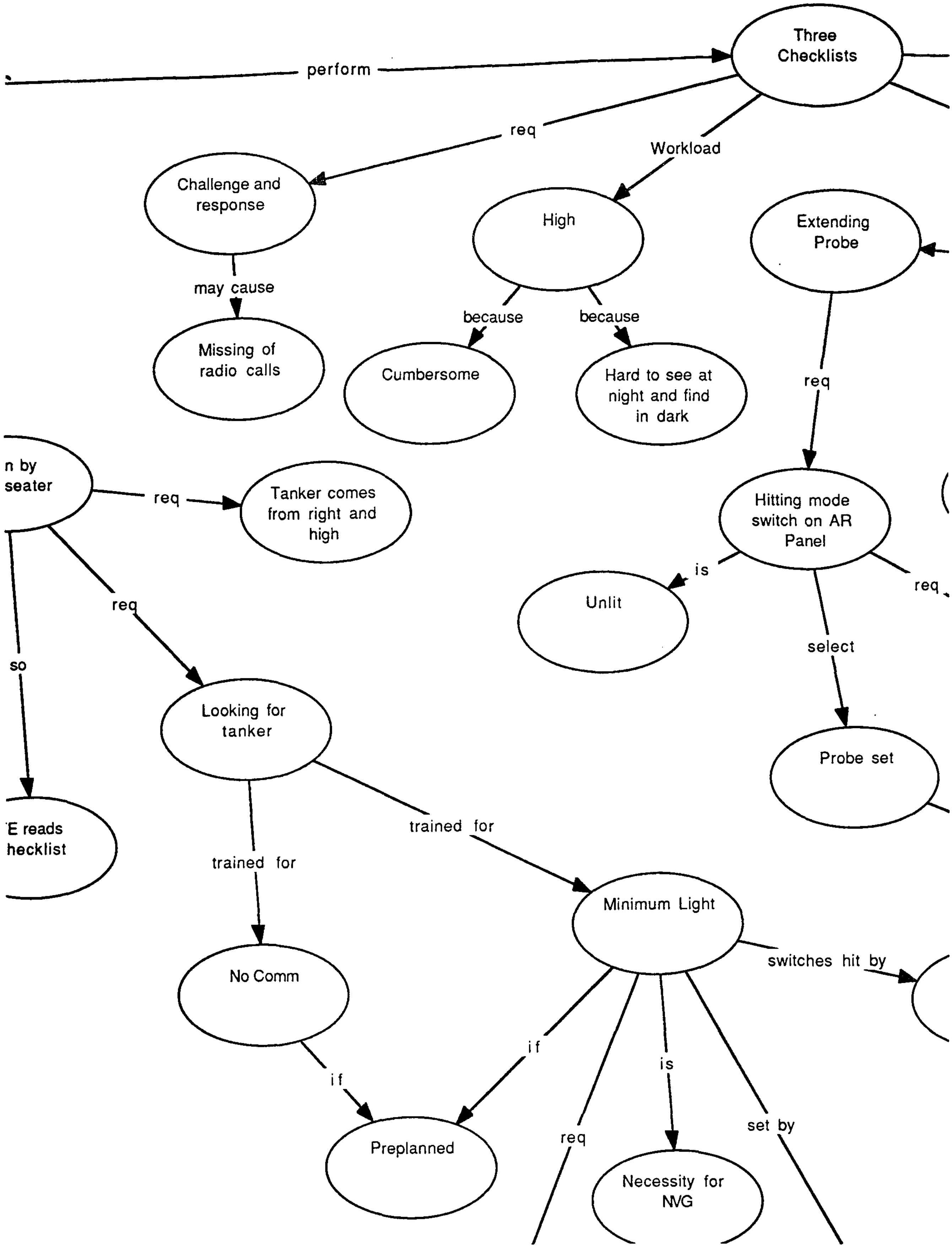

Control Point
called
Navigation to designated point
tanker
specifies
req
is
must be
Runs left of formation
Direction Alt and speed
Timing
3 min from IP
On speed and Alt.
req
Tanker overtake of AC
req
is
can be
Constant Comparisons
Entered from any direction (Tanker & AC)
is
of
No speed que
Arrival time ARCT is 2000 and TTG
means
on
on
Must recalculate speed
Cover TTG corner screen
means
Top of screen (arrival time)
Making mistakes
Wa

It's no
pilots c
che

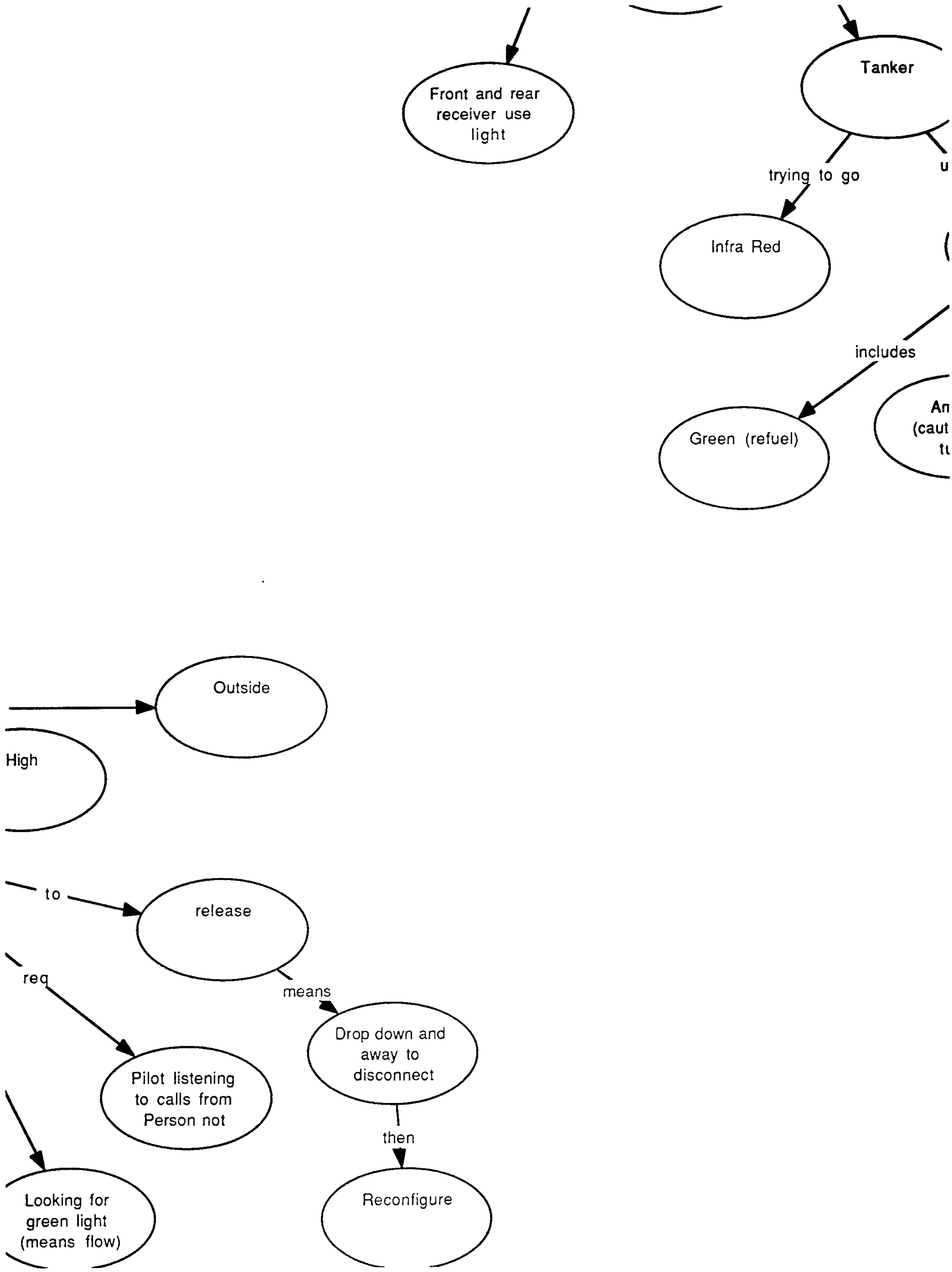


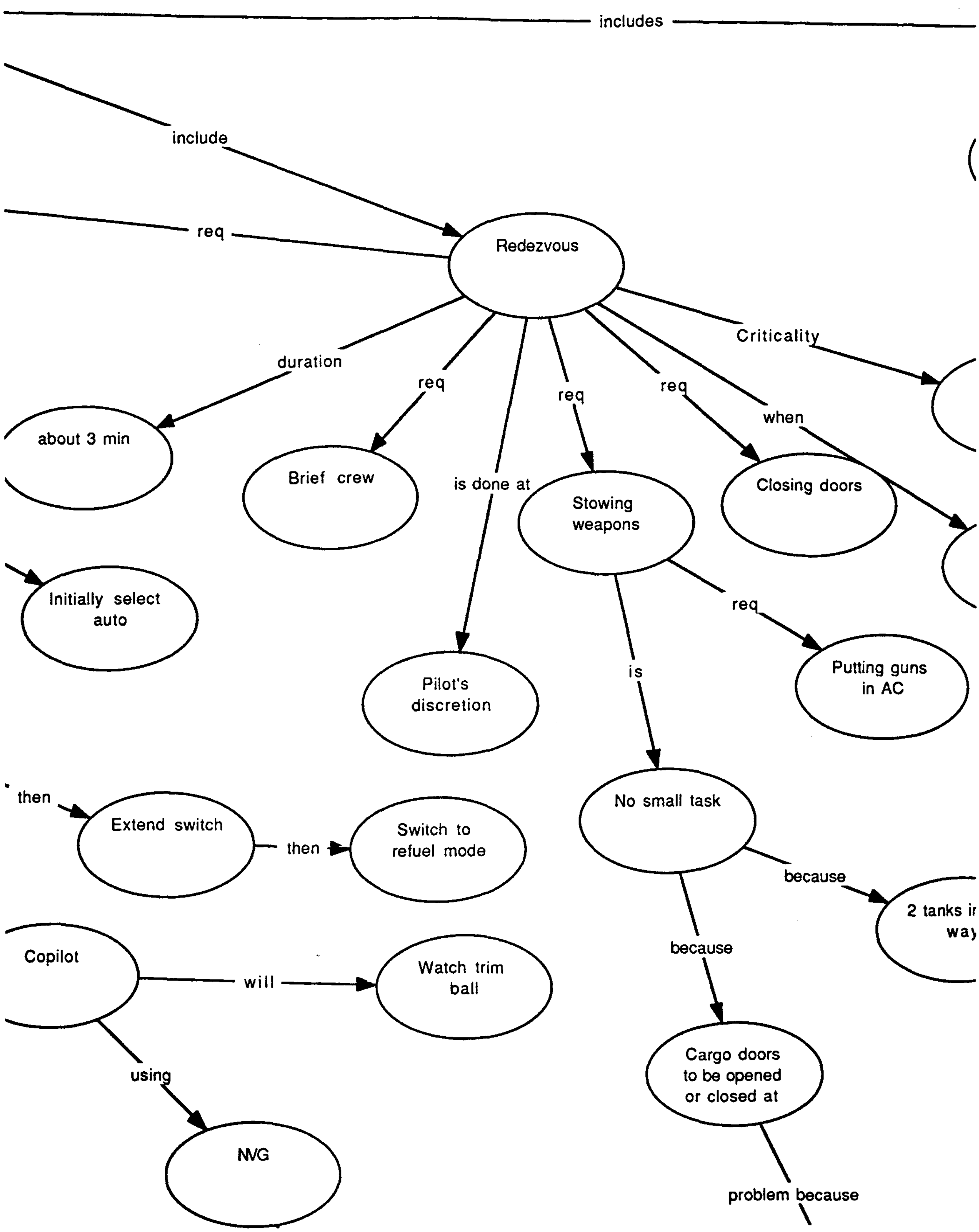
Aerial Refueling
req
Wkld
High
Criticality
High
due to
Most difficult part
due to
workload
is
low for pilot
is
Flow right
from
App IP
req
Maintaining Spacing
by
Pilot Flying
means
Left seat is switch man or navigator
will
will
could be
tch gas gauge
Come inside cockpit
to
A problem
such as


Change position light to flashing
during
Simultaneous refueling at release
is
Located Overhead
is
Hard to see; especially for pilot flying
means
t in
ross
ck
Nav error
ie
Drifting Nav sensor or bad timing
is
Looking for light
is
Indication to Fly to drogue
then
Position Probe to drogue
workload
Enviromnent dependent
means
Low workload in good conditions
means
High workload in bad conditions
is
Primarily a hands manuever
then
Maintain Position
Display
Criticality
is
Focused outside AC
to
Contact
req
Pushing hose to interval
has
Problems
req
such as
Judging range
is what
Majority of time spent on

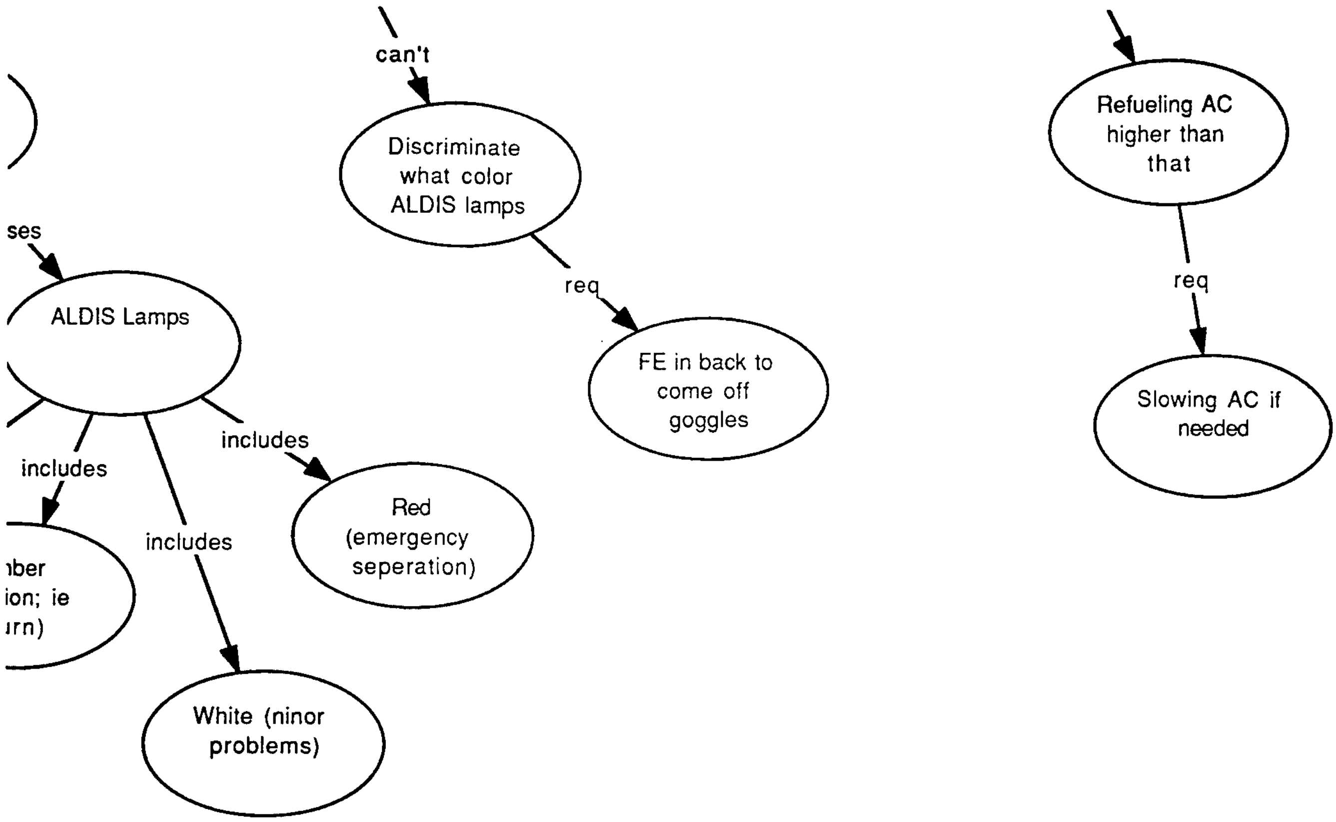


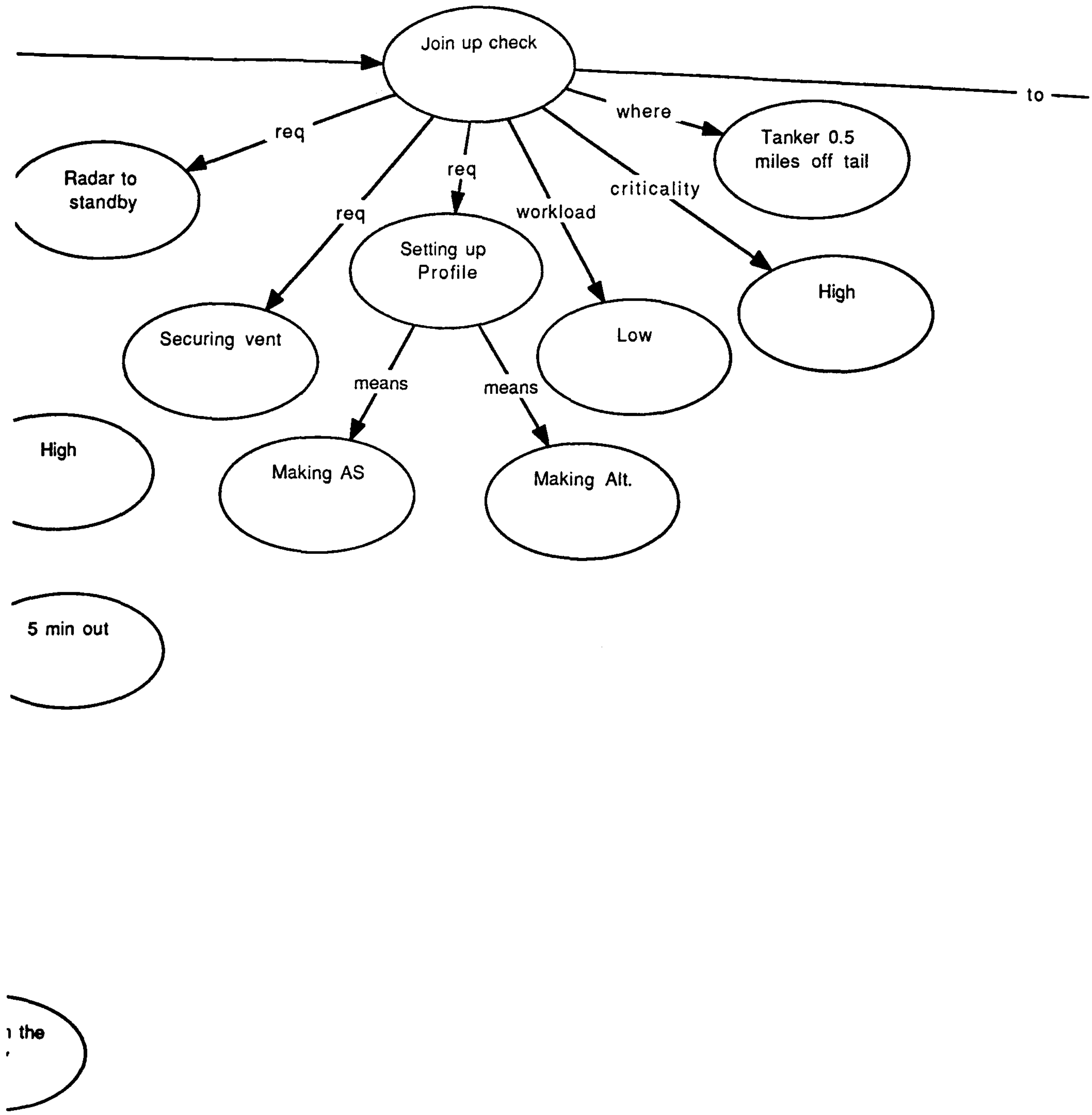
perform
Three Checklists
req
Workload
Challenge and response
High
Extending Probe
may cause
because
because
Missing of radio calls
Cumbersome
Hard to see at night and find in dark
req
n by seater
req
Tanker comes from right and high
Hitting mode switch on AR Panel
is
req
req
Unlit
so
select
Looking for tanker
Probe set
E reads hecklist
trained for
trained for
Minimum Light
switches hit by
No Comm
if
is
if
set by
req
Preplanned
Necessity for NVG

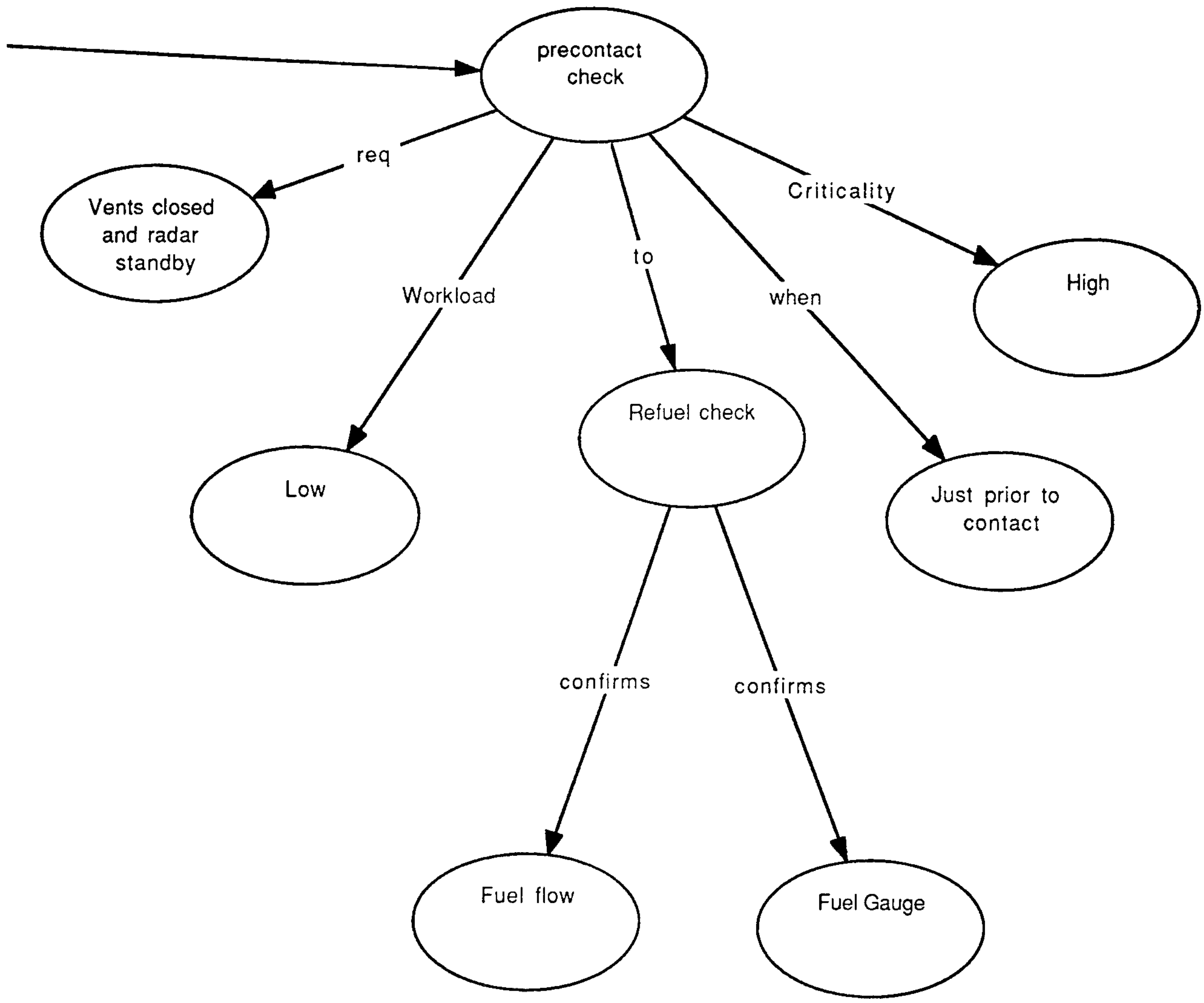

Front and rear receiver use light
Tanker
trying to go
u
Infra Red
includes
Green (refuel)
An
(caut
tu
Outside
High
to
release
req
means
Drop down and away to disconnect
Pilot listening to calls from Person not
then
Looking for green light (means flow)
Reconfigure



includes
include
req
Redezvous
duration
req
req
req
Criticality
when
about 3 min
Brief crew
is done at
Stowing weapons
Closing doors
Initially select auto
req
Pilot's discretion
is
Putting guns in AC
then
Extend switch
then
Switch to refuel mode
No small task
because
2 tanks i
wa
because
Copilot
will
Watch trim ball
using
NVG
Cargo doors to be opened or closed at
problem because


can't
Discriminate what color ALDIS lamps
req
FE in back to come off goggles
Refueling AC higher than that
req
Slowing AC if needed
ses
ALDIS Lamps
includes
includes
includes
Red (emergency seperation)
ıber
ion; ie
ırn)
White (ninor problems)


Join up check
to
req
where
Radar to standby
Tanker 0.5 miles off tail
req
req
criticality
req
workload
Setting up Profile
High
Securing vent
Low
means
means
High
Making AS
Making Alt.
5 min out
the



precontact check
req
Vents closed and radar standby
Workload
Low
to
Refuel check
when
Just prior to contact
Criticality
High
confirms
confirms
Fuel flow
Fuel Gauge

Aerial Refueling Map Outline

Aerial Refueling req Navigation to designated point.
Navigation to designated point called Control Point.
Control Point is 3 min from IP.
3 min from IP can be Entered from any direction (Tanker & AC).
Control Point must be On speed and Alt.
Control Point tanker Runs left of formation.
Runs left of formation req Tanker overtake of AC.
Navigation to designated point specifies Direction Alt and speed.
Navigation to designated point req Timing.
Timing is Most difficult part.
Most difficult part due to workload.
workload is low for pilot.
Timing req Constant Comparisons.
Constant Comparisons of Arrival time ARCT is 2000 and TTG.
Arrival time ARCT is 2000 and TTG on Cover TTG corner screen.
Arrival time ARCT is 2000 and TTG on Top of screen (arrival time).
Constant Comparisons is No speed que.
No speed que means Must recalculate speed.
Must recalculate speed means Making mistakes.
Navigation to designated point Criticality High.
High due to Timing.
Navigation to designated point Wkld High.
Aerial Refueling is Flown by right seater.
Flown by right seater means Left seat is switch man or navigator.
Left seat is switch man or navigator will Watch gas gauge.
Left seat is switch man or navigator will Come inside cockpit.
Come inside cockpit to Change position light to flashing.
Change position light to flashing during Simultaneous refueling at release.
Change position light to flashing is Located Overhead.
Located Overhead is Hard to see; especially for pilot flying.
Hard to see; especially for pilot flying means It's not in pilots cross check.
Left seat is switch man or navigator could be A problem.
A problem such as Nav error.
Nav error ie Drifting Nav sensor or bad timing.
Flown by right seater from App IP.
App IP req Maintaining Spacing.
Maintaining Spacing by Pilot Flying.
Pilot Flying is Looking for light.
Looking for light is Indication to Fly to drogue.
Indication to Fly to drogue then Position Probe to drogue.
Position Probe to drogue workload Environment dependent.
Environment dependent means Low workload in good conditions.

Environment dependent means High workload in bad conditions.
Position Probe to drogue is Primarily a hands maneuver.
Position Probe to drogue then Maintain Position.
Maintain Position is Focused outside AC.
Maintain Position to Contact.
Contact req Pushing hose to interval.
Contact has Problems.
Problems such as Judging range.
Judging range is what Majority of time spent on.
Contact req Pilot listening to calls from Person not Flying.
Contact req Looking for green light (means flow).
Contact to release.
release means Drop down and away to disconnect.
Drop down and away to disconnect then Reconfigure.
Maintain Position Criticality High.
Maintain Position Display Outside.
Flown by right seater req Looking for tanker.
Looking for tanker trained for No Comm.
No Comm if Preplanned.
Looking for tanker trained for Minimum Light.
Minimum Light if Preplanned.
Minimum Light req Front and rear receiver use light.
Minimum Light is Necessity for NVG.
Minimum Light set by Tanker.
Tanker trying to go Infra Red.
Tanker uses ALDIS Lamps.
ALDIS Lamps includes Green (refuel).
ALDIS Lamps includes Amber (caution; ie turn).
ALDIS Lamps includes White (minor problems).
ALDIS Lamps includes Red (emergency seperation).
Minimum Light switches hit by Copilot.
Copilot will Watch trim ball.
Copilot using NVG.
NVG can't Discriminate what color ALDIS lamps are.
Discriminate what color ALDIS lamps are req FE in back to come off goggles.
Flown by right seater so FE reads checklist.
Flown by right seater req Tanker comes from right and high.
Aerial Refueling perform Three Checklists.
Three Checklists req Challenge and response.
Challenge and response may cause Missing of radio calls.
Three Checklists include Redezvous.
Redezvous req Extending Probe.
Extending Probe req Hitting mode switch on AR Panel.
Hitting mode switch on AR Panel select Probe set.

Probe set then Extend switch.
Extend switch then Switch to refuel mode.
Hitting mode switch on AR panel is Unlit.
Hitting mode switch on AR Panel req Initially select auto.
Redezvous duration about 3 min.
Redezvous req Brief crew.
Redezvous is done at Pilot's discretion.
Redezvous req Stowing weapons.
Stowing weapons is No small task.
No small task because Cargo doors to be opened or closed at 100 Kts.
Cargo doors to be opened or closed at 100 Kts problem because Refueling AC higher than that.
Refueling AC higher than that req Slowing AC if needed.
No small task because 2 tanks in the way.
Stowing weapons req Putting guns in AC.
Redezvous req Closing doors.
Redezvous when 5 min out.
Redezvous Criticality High.
Three Checklists Workload High.
High because Cumbersome.
High because Hard to see at night and find in dark.
Three Checklists includes Join up check.
Join up check req Radar to standby.
Join up check req Securing vent.
Join up check req Setting up Profile.
Setting up Profile means Making AS.
Setting up Profile means Making Alt..
Join up check workload Low.
Join up check criticality High.
Join up check where Tanker 0.5 miles off tail.
Join up check to precontact check.
precontact check req Vents closed and radar standby.
precontact check to Refuel check.
Refuel check confirms Fuel flow.
Refuel check confirms Fuel Gauge.
precontact check when Just prior to contact.
precontact check Criticality High.
precontact check Workload Low.

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Night Water Hoist Concept Map

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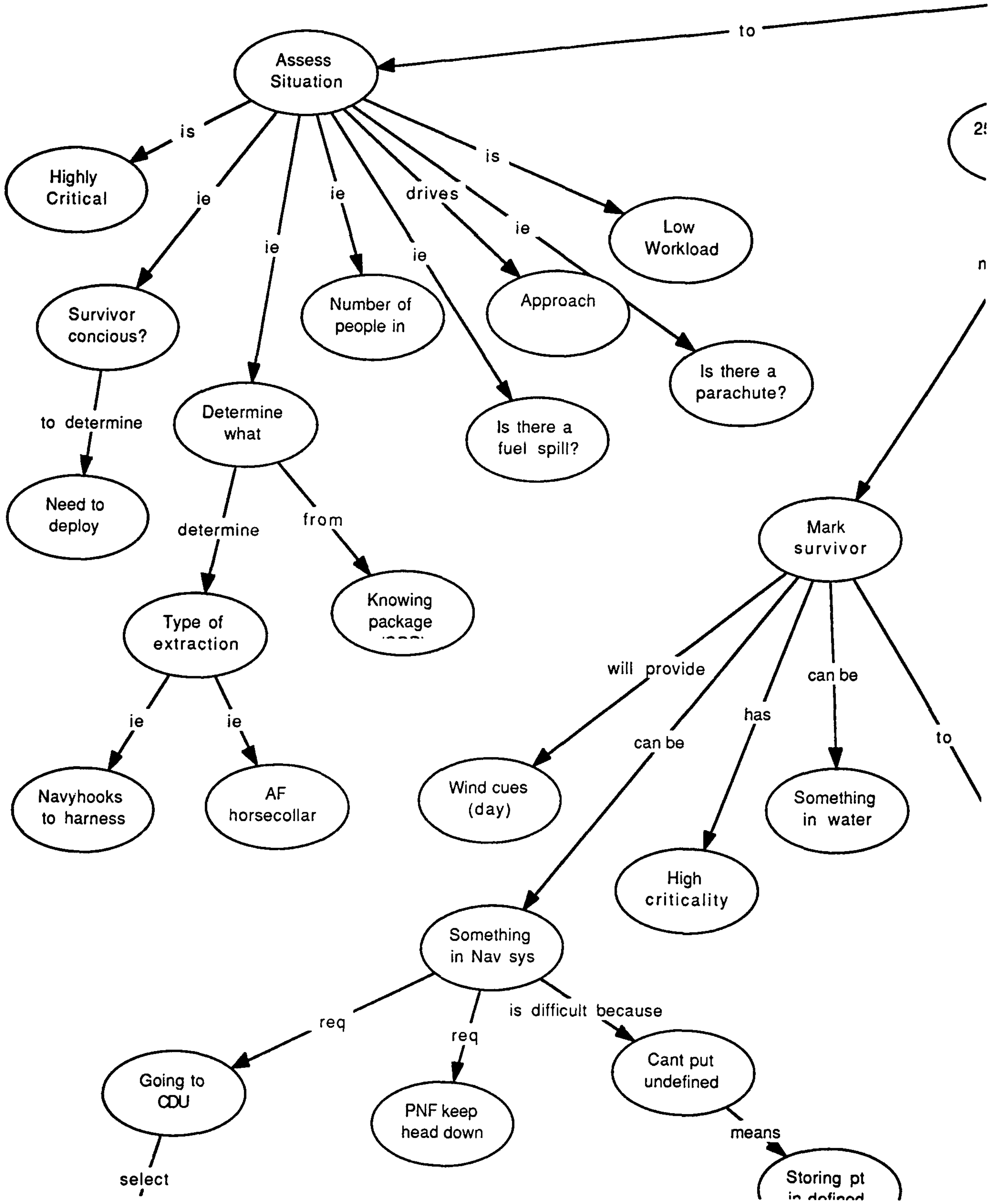
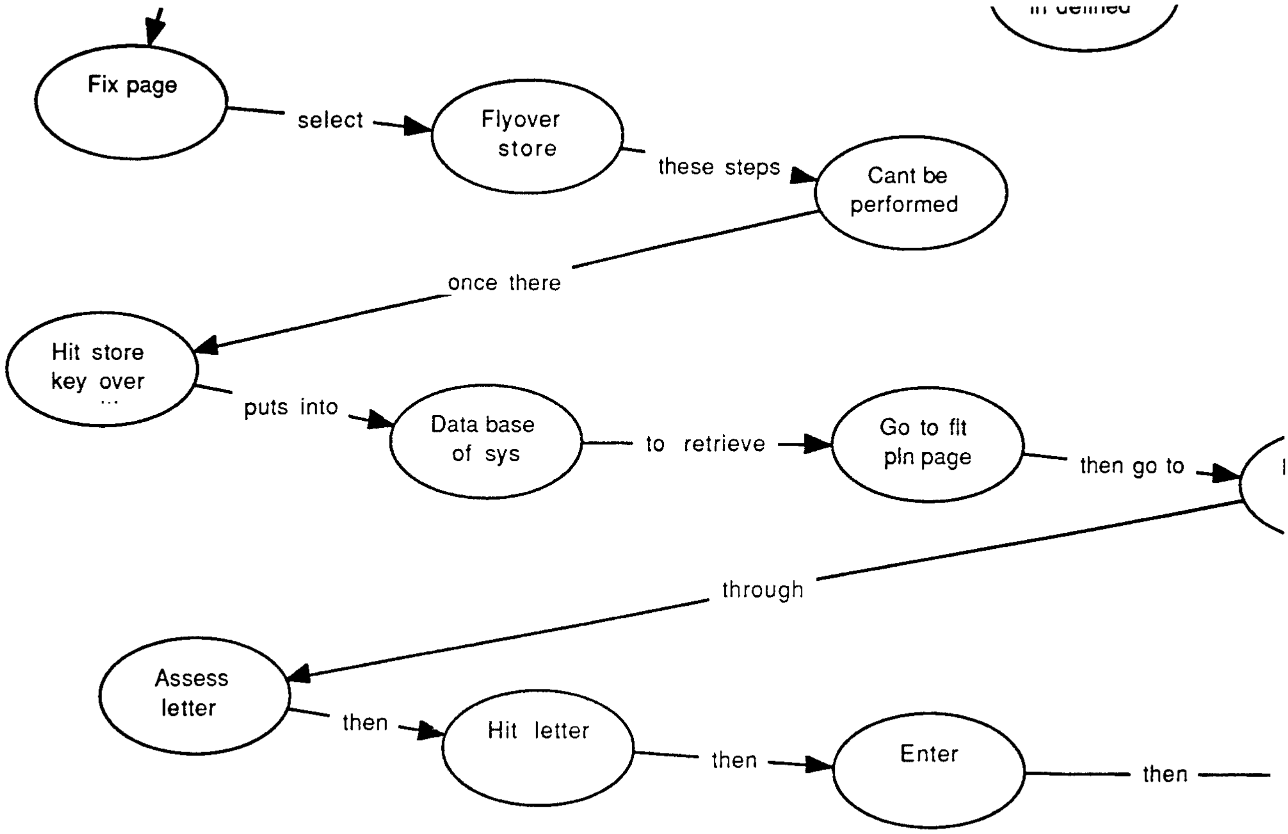
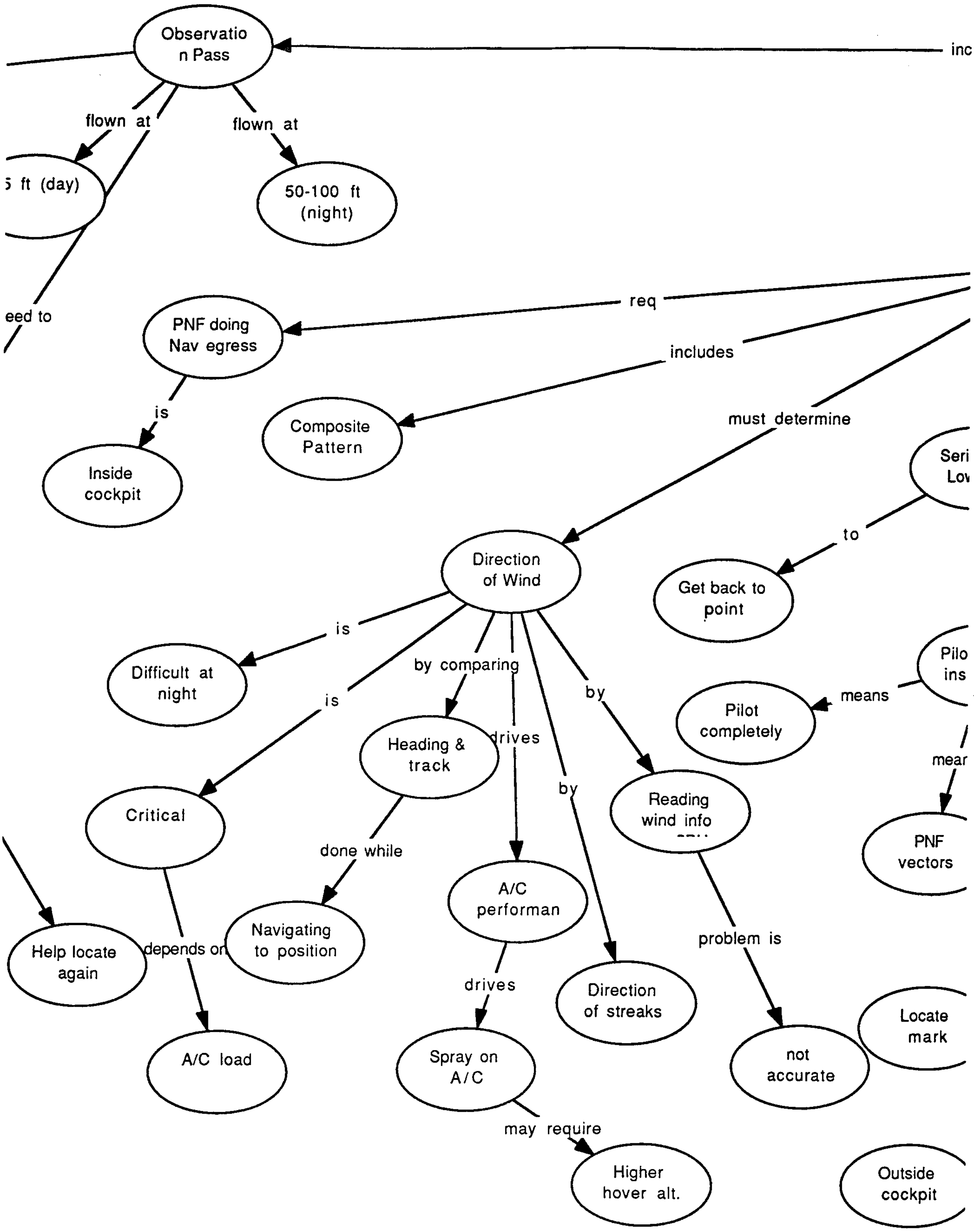
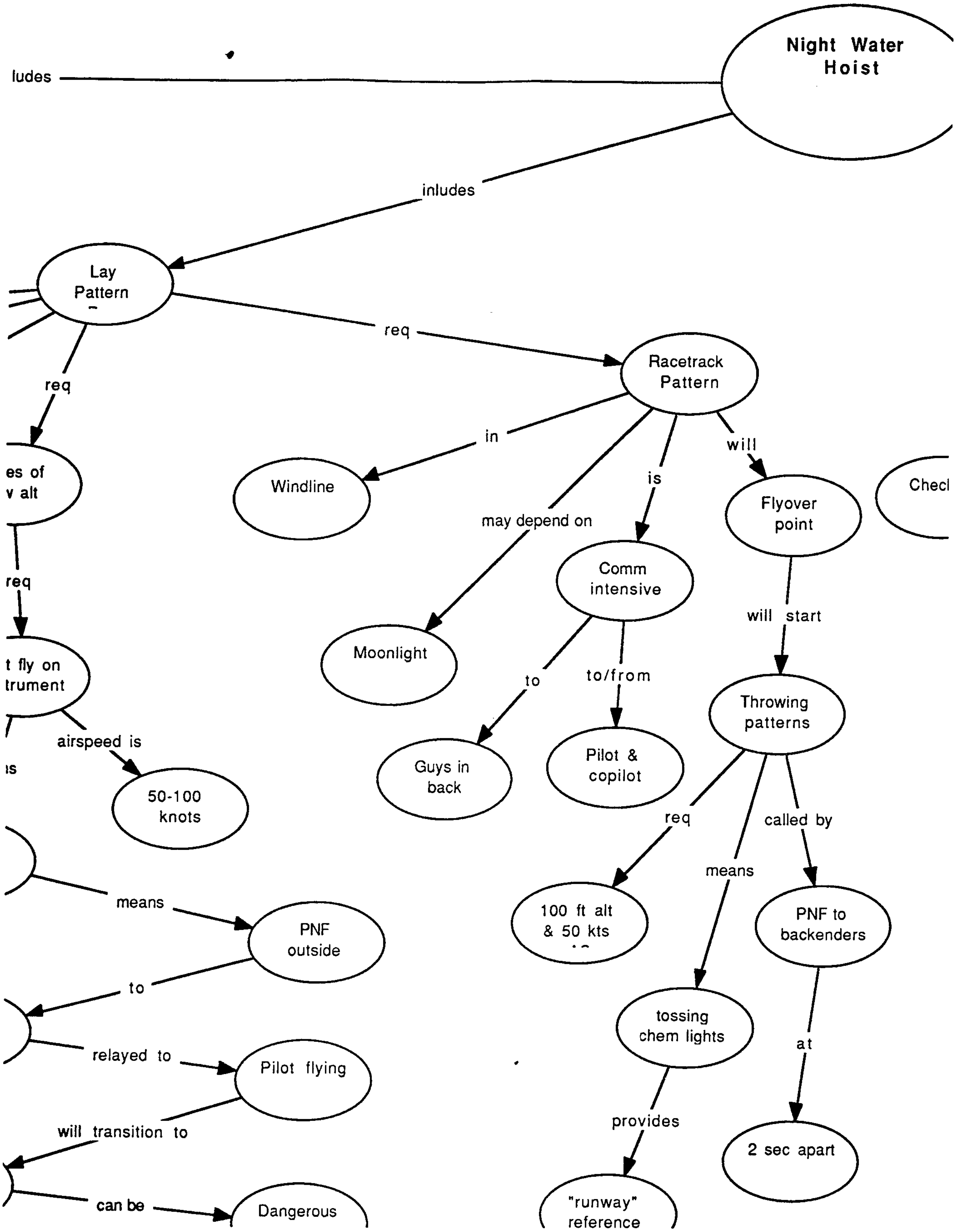

to
Assess Situation
is
Highly Critical
ie
Survivor concious?
to determine
Need to deploy
ie
Determine what
determine
Type of extraction
ie
Navyhooks to harness
ie
AF horsecollar
from
Knowing package
ie
Number of people in
ie
Is there a fuel spill?
drives
Approach
ie
Is there a parachute?
is
Low Workload
Mark survivor
will provide
Wind cues (day)
can be
Something in Nav sys
req
Going to CDU
select
req
PNF keep head down
is difficult because
Cant put undefined
means
Storing pt
has
High criticality
can be
Something in water
to

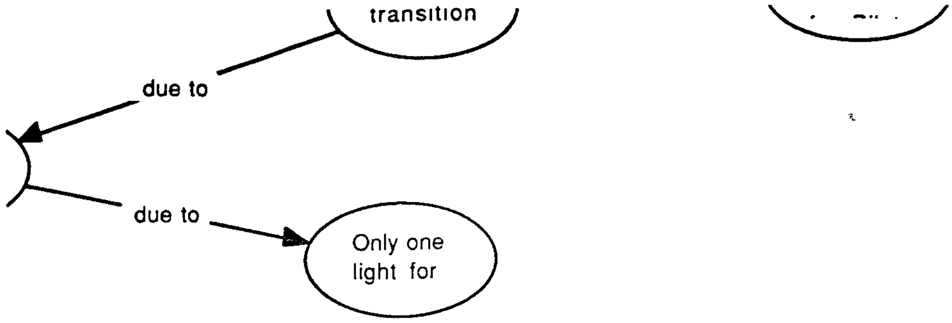

Fix page
select
Flyover store
these steps
Cant be performed
once there
Hit store key over
puts into
Data base of sys
to retrieve
Go to flt pln page
then go to
through
Assess letter
then
Hit letter
then
Enter
then

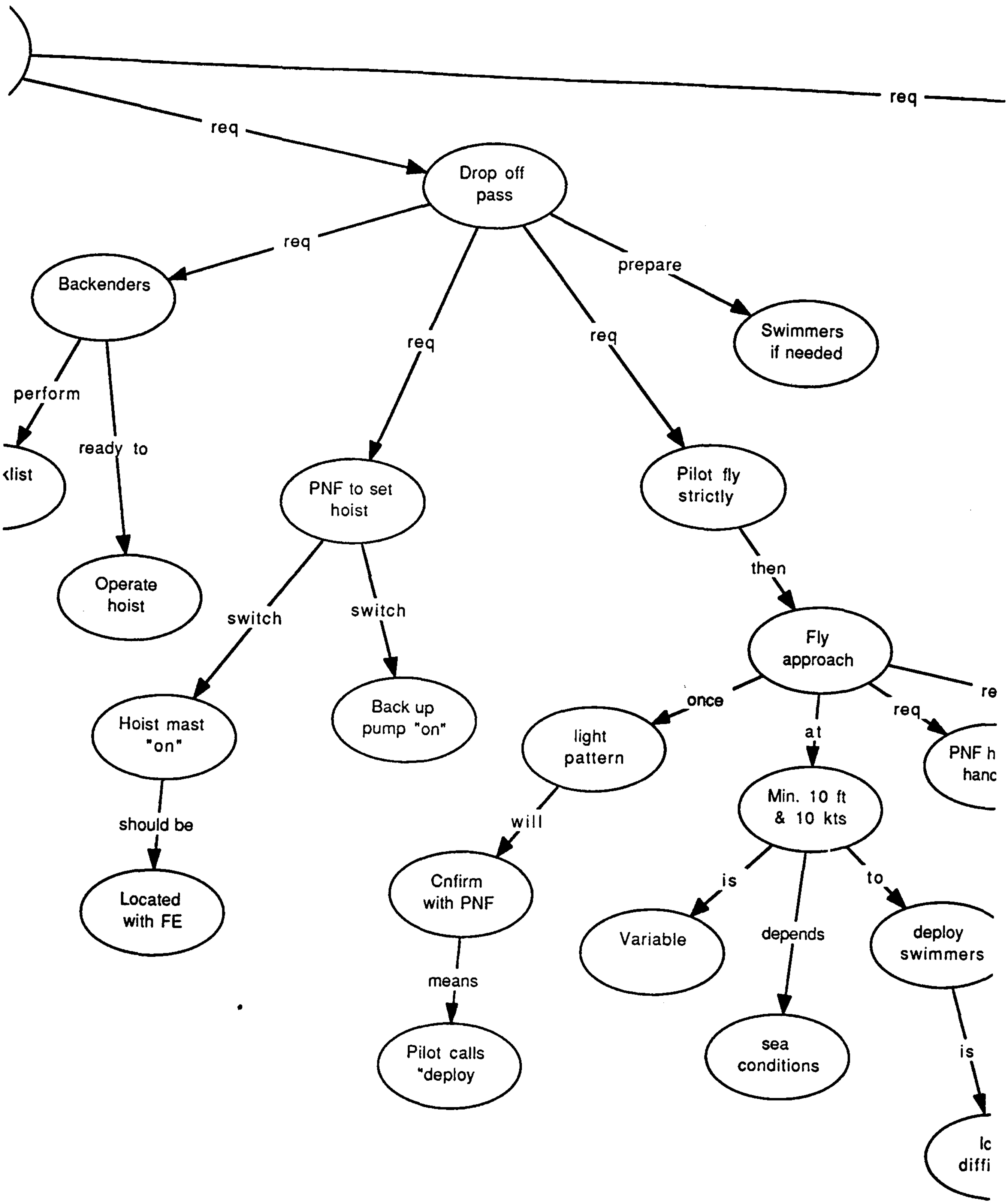


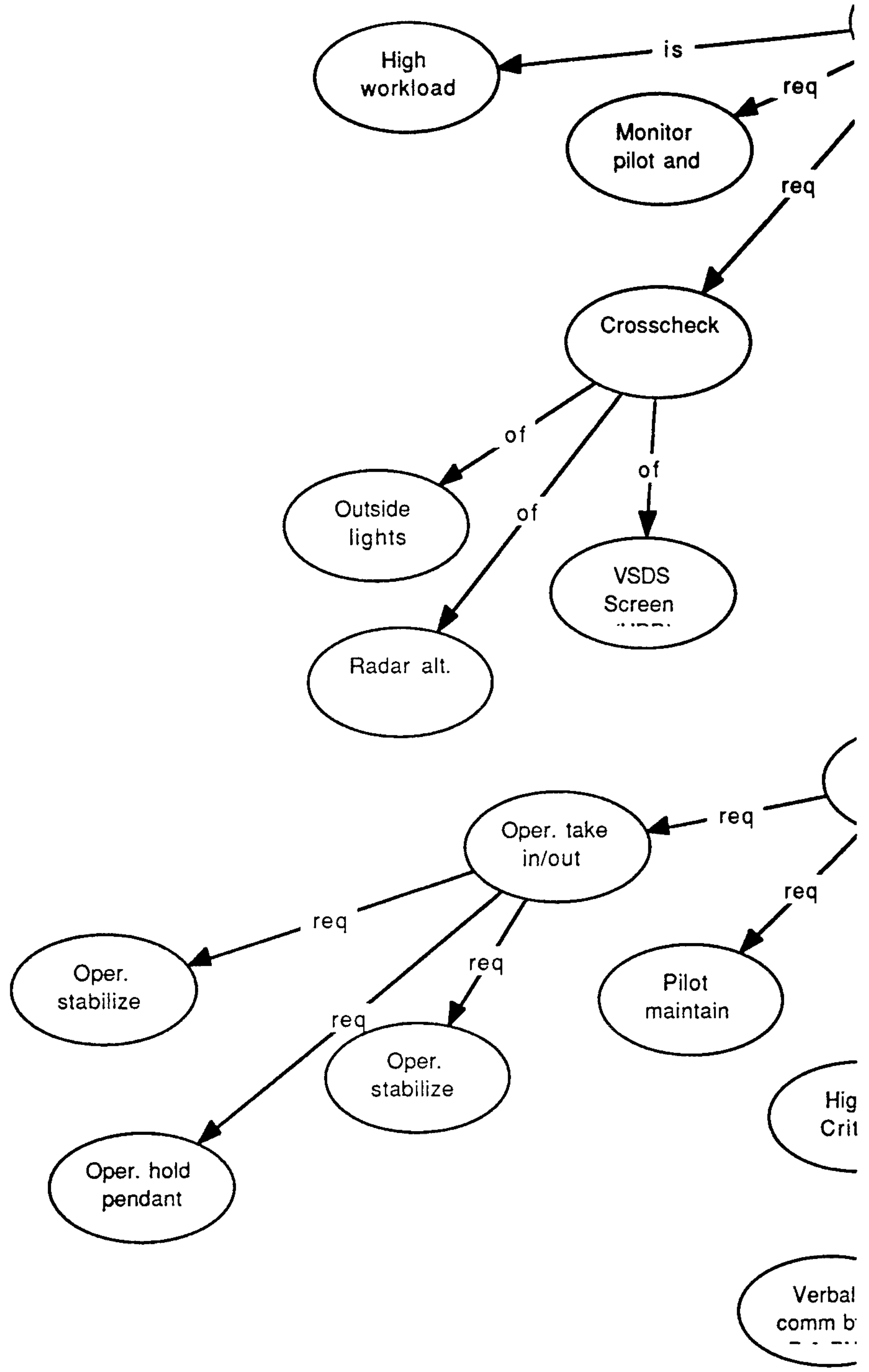
Observatio n Pass
inc
flown at
flown at
5 ft (day)
50-100 ft (night)
eed to
req
PNF doing Nav egress
includes
is
Composite Pattern
must determine
Inside cockpit
Seri Lov
to
Direction of Wind
Get back to point
is
by comparing
Difficult at night
by
Pilo ins
means
is
Pilot completely
Heading & track
drives
mear
by
Critical
Reading wind info
PNF vectors
done while
A/C performan
Help locate again
depends on
Navigating to position
problem is
drives
Direction of streaks
Locate mark
A/C load
Spray on A/C
not accurate
may require
Higher hover alt.
Outside cockpit


Disorientat
ion
Direct flt
plan
Back to
steering

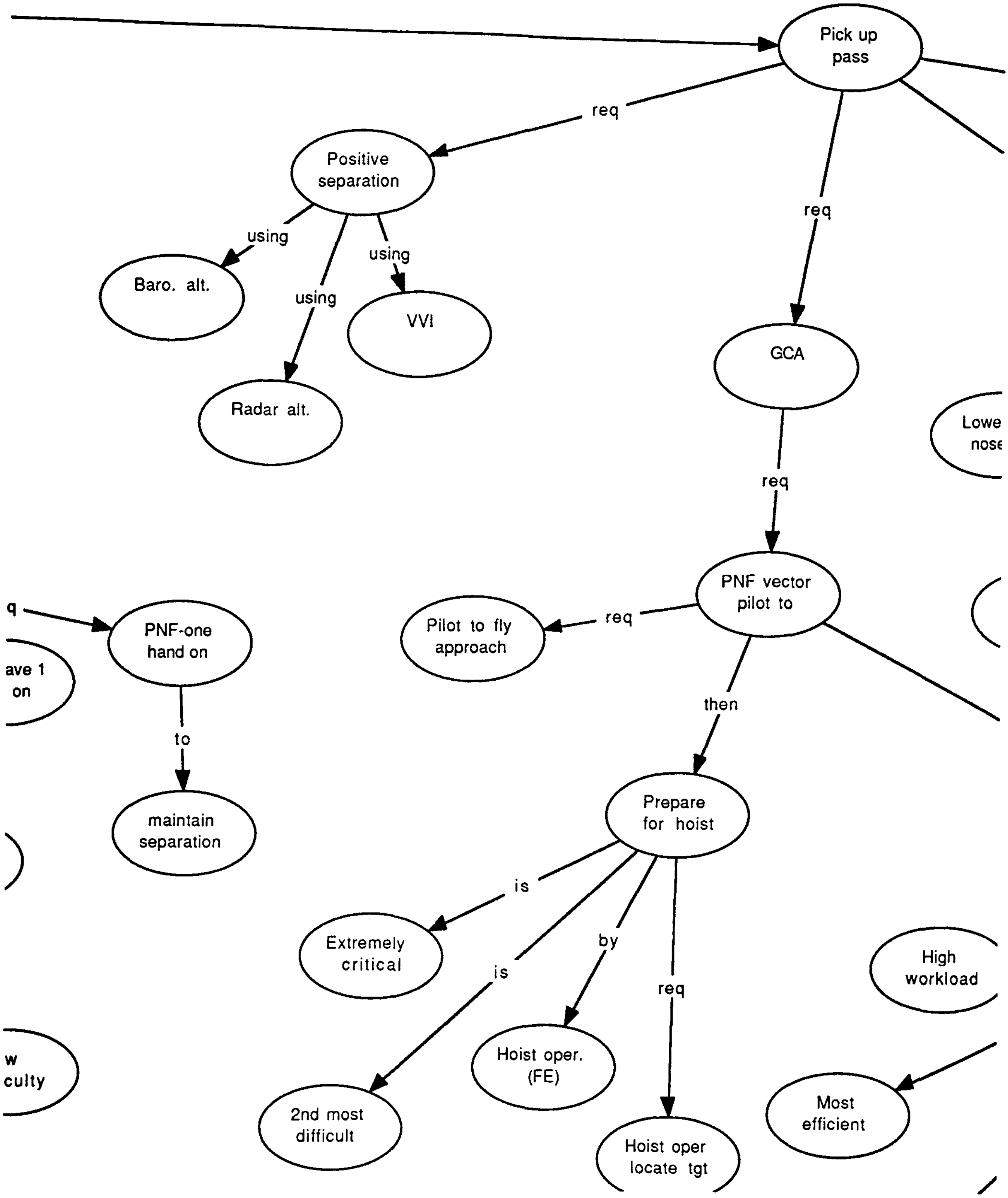

Night Water Hoist
ludes
inludes
Lay Pattern
req
Racetrack Pattern
req
es of
v alt
req
t fly on
trument
airspeed is
50-100 knots
in
Windline
may depend on
Moonlight
is
Comm intensive
to
Guys in back
to/from
Pilot & copilot
will
Flyover point
Checl
will start
Throwing patterns
req
100 ft alt & 50 kts
means
tossing chem lights
provides
"runway" reference
called by
PNF to backenders
at
2 sec apart
means
PNF outside
to
relayed to
Pilot flying
will transition to
can be
Dangerous

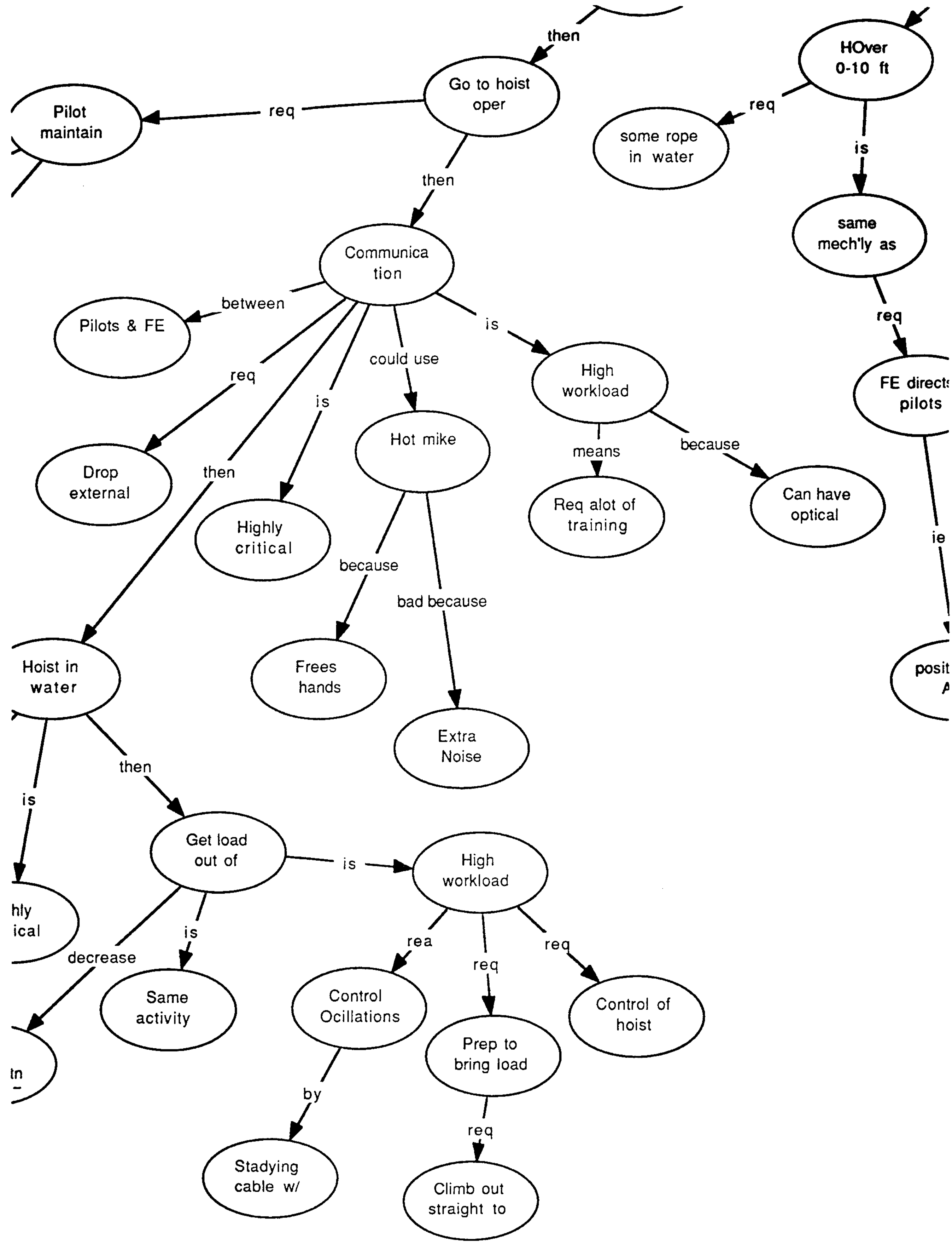

transition
due to
due to
Only one
light for

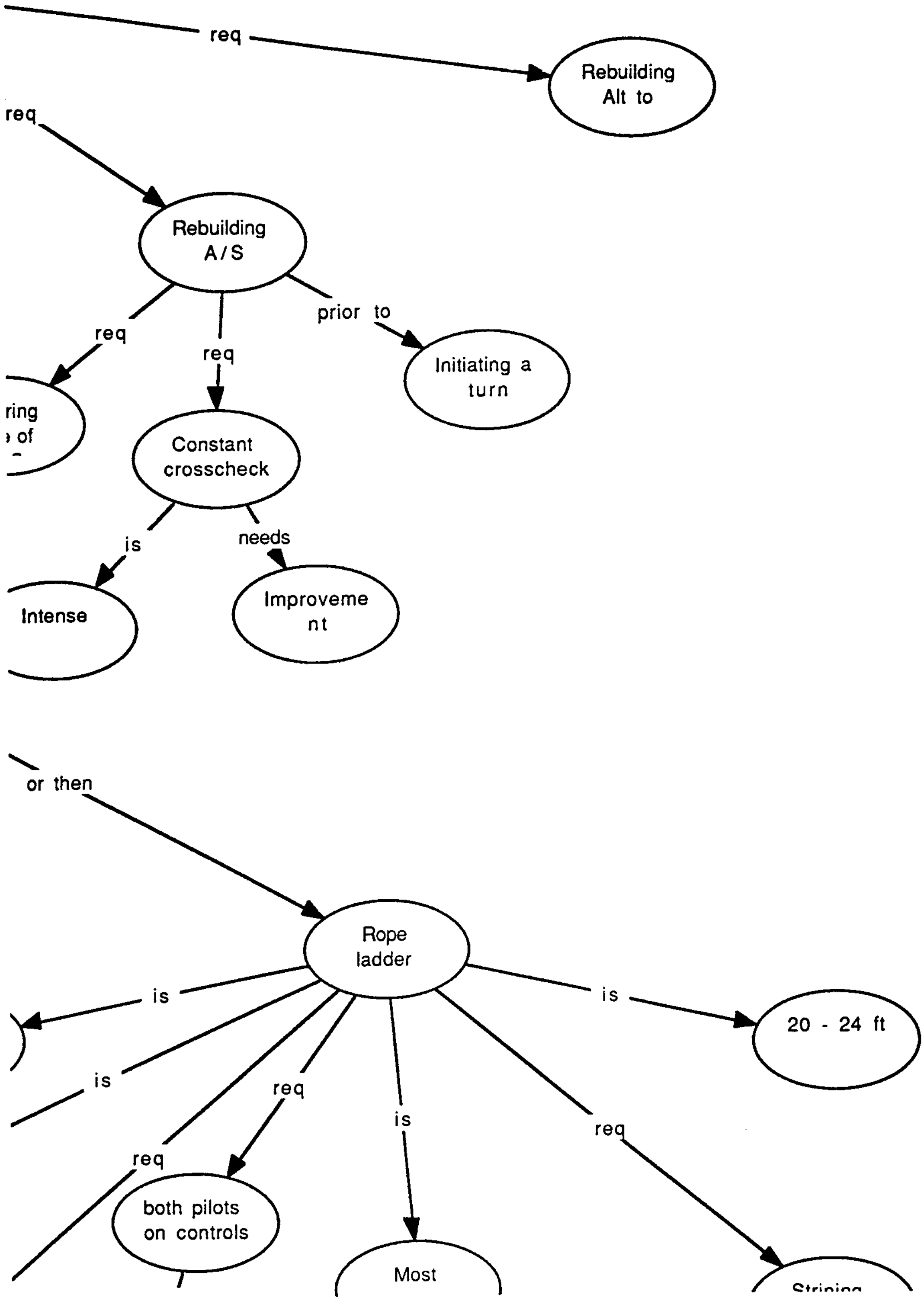

req
req
Drop off pass
req
Backenders
prepare
Swimmers if needed
req
req
perform
ready to
‹list
PNF to set hoist
Pilot fly strictly
Operate hoist
then
switch
switch
Fly approach
Hoist mast "on"
Back up pump "on"
once
re
req
at
light pattern
PNF h hanc
should be
Min. 10 ft & 10 kts
will
Located with FE
Cnfirm with PNF
is
to
Variable
depends
deploy swimmers
means
Pilot calls "deploy
sea conditions
is
lc diffi

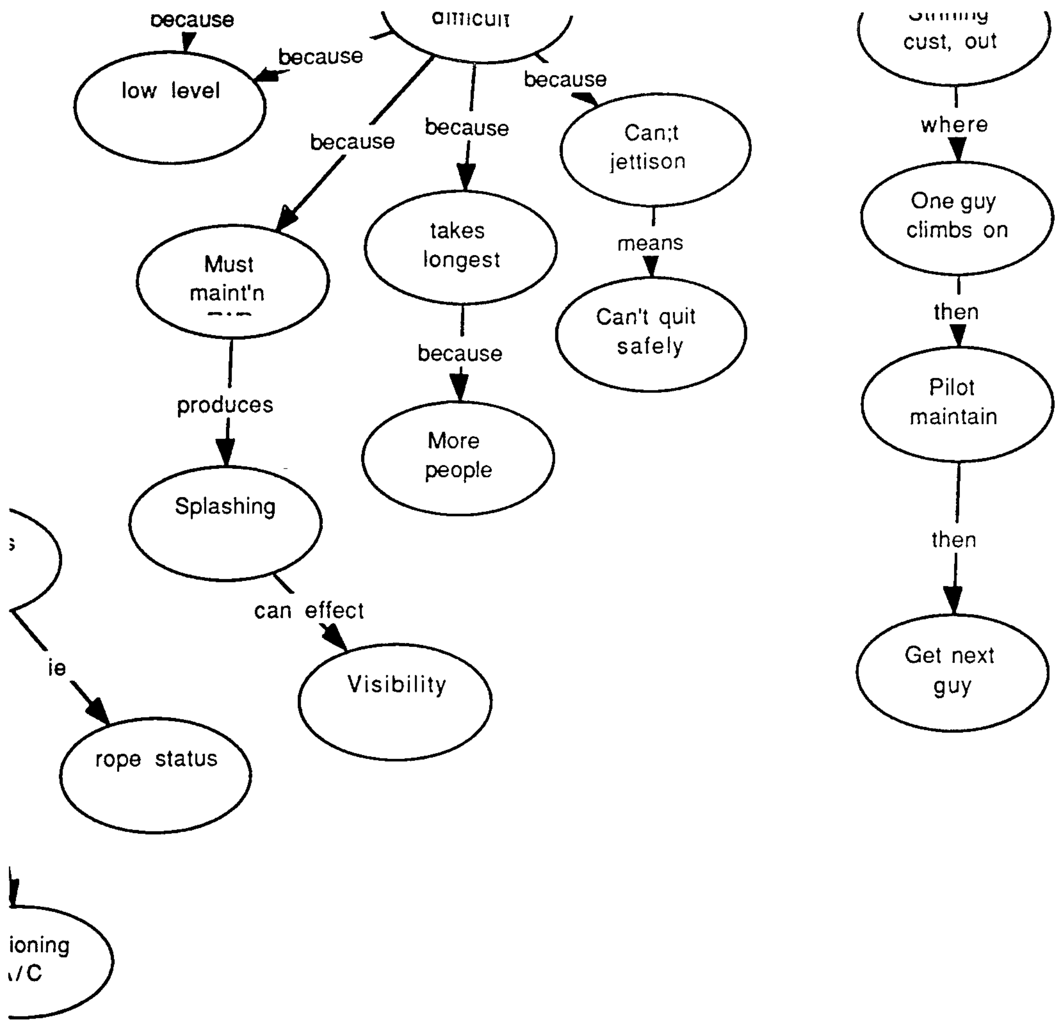


High workload
is
req
Monitor pilot and
req
Crosscheck
of
of
of
Outside lights
VSDS Screen
Radar alt.
Oper. take in/out
req
req
req
req
req
Oper. stabilize
Pilot maintain
Oper. stabilize
Oper. hold pendant
Hig
Crit
Verbal
comm b


Pick up pass
req
Positive separation
using
Baro. alt.
using
Radar alt.
using
VVI
req
GCA
req
PNF vector pilot to
req
Pilot to fly approach
then
Prepare for hoist
is
Extremely critical
is
2nd most difficult
by
Hoist oper. (FE)
req
Hoist oper locate tgt
Lowe nose
High workload
Most efficient
q
PNF-one hand on
to
maintain separation
ave 1 on
w culty


then
Go to hoist oper
req
Pilot maintain
then
Communica tion
between
Pilots & FE
req
Drop external
then
is
Highly critical
could use
Hot mike
because
Frees hands
bad because
Extra Noise
is
High workload
means
Req alot of training
because
Can have optical
HOver 0-10 ft
req
some rope in water
is
same mech'ly as
req
FE directs pilots
ie
Hoist in water
is
then
Get load out of
is
Same activity
decrease
is
High workload
rea
Control Ocillations
by
Stadying cable w/
req
Prep to bring load
req
Climb out straight to
req
Control of hoist


req
Rebuilding
Alt to
req
Rebuilding
A/S
req
req
prior to
ring
of
Initiating a
turn
Constant
crosscheck
is
needs
Intense
Improveme
nt
or then
Rope
ladder
is
is
is
20 - 24 ft
req
is
req
req
both pilots
on controls
Most


because
difficult
because
low level
because
because
because
Can;t jettison
Must maint'n
takes longest
means
Can't quit safely
because
produces
More people
Splashing
can effect
Visibility
ie
rope status
ioning
/C
cust, out
where
One guy climbs on
then
Pilot maintain
then
Get next guy

Night Water Hoist Map Outline

Night Water Hoist req Pick up pass.
Pick up pass req GCA.
GCA req PNF vector pilot to mark.
PNF vector pilot to mark then Prepare for hoist.
Prepare for hoist req Hoist oper locate tgt.
Hoist oper locate tgt then Go to hoist oper directed hover.
Go to hoist oper directed hover then Communication.
Communication is High workload for FE.
High workload for FE because Can have optical illusions.
High workload for FE means Req alot of training.
Communication could use Hot mike.
Hot mike bad because Extra Noise.
Hot mike because Frees hands.
Communication is Highly critical.
Communication then Hoist in water.
Hoist in water then Get load out of water.
Get load out of water is High workload for FE.
High workload for FE req Control of hoist movements.
High workload for FE req Prep to bring load in A/C.
Prep to bring load in A/C req Climb out straight to depart.
High workload for FE rea Control Ocillations.
Control Ocillations by Stadying cable w/ hands.
Get load out of water is Same activity level for pilots.
Get load out of water decrease Verbal comm btn P & PNF.
Hoist in water is Highly Critical.
Hoist in water req Pilot maintain A/C vertical mov't.
Hoist in water req Oper. take in/out slack.
Oper. take in/out slack req Oper. stabilize cable.
Oper. take in/out slack req Oper. hold pendant.
Oper. take in/out slack req Oper. stabilize self.
Communication req Drop external comm..
Communication between Pilots & FE.
Go to hoist oper directed hover req Pilot maintain stable hover.
Pilot maintain stable hover req Crosscheck.
Crosscheck of VSDS Screen (HDD).
Crosscheck of Radar alt..
Crosscheck of Outside lights.
Pilot maintain stable hover req Monitor pilot and A/C sys's.
Pilot maintain stable hover is High workload.
Prepare for hoist by Hoist oper. (FE).
Prepare for hoist is 2nd most difficult task.
Prepare for hoist is Extremely critical.

PNF vector pilot to mark req Pilot to fly approach to hover.
PNF vector pilot to mark or then Rope ladder recovery.
Rope ladder recovery is High workload.
Rope ladder recovery is Most efficient pickup method.
Rope ladder recovery req HOver 0-10 ft over water.
HOver 0-10 ft over water req some rope in water.
HOver 0-10 ft over water is same mech'ly as hoist.
same mech'ly as hoist req FE directs pilots.
FE directs pilots ie positioning A/C.
FE directs pilots ie rope status.
Rope ladder recovery req both pilots on controls.
both pilots on controls because low level.
Rope ladder recovery is Most difficult recovery.
Most difficult recovery because low level.
Most difficult recovery because Must maint'n FWD mvmt, LL.
Must maint'n FWD mvmt, LL produces Splashing.
Splashing can effect Visibility.
Most difficult recovery because takes longest.
takes longest because More people.
Most difficult recovery because Can;t jettison ladder.
Can;t jettison ladder means Can't quit safely.
Rope ladder recovery req Strining cust, out on line.
Strining cust, out on line where One guy climbs on.
One guy climbs on then Pilot maintain fwd mvmt.
Pilot maintain fwd mvmt then Get next guy.
Rope ladder recovery is 20 - 24 ft.
Pick up pass req Positive separation from water.
Positive separation from water using VVI.
Positive separation from water using Radar alt.
Positive separation from water using Baro. alt.
Pick up pass req Rebuilding A/S.
Rebuilding A/S req Lowering nose of A/C.
Rebuilding A/S req Constant crosscheck.
Constant crosscheck is Intense.
Constant crosscheck needs Improvement.
Rebuilding A/S prior to Initiating a turn.
Pick up pass req Rebuilding Alt to 1000 ft.Night Water Hoist req Drop off pass.
Drop off pass prepare Swimmers if needed.
Drop off pass req Pilot fly strictly outside.
Pilot fly strictly outside then Fly approach to hover.
Fly approach to hover req PNF-one hand on collective.
PNF-one hand on collective to maintain separation from water.
Fly approach to hover req PNF have 1 hand on wiper.
Fly approach to hover at Min. 10 ft & 10 kts.
Min. 10 ft & 10 kts to deploy swimmers.

deploy swimmers is low difficulty.
Min. 10 ft & 10 kts depends sea conditions.
Min. 10 ft & 10 kts is Variable.
Fly approach to hover once light pattern.
light pattern will Cnfirm with PNF at 10 ft & 10 kts.
Cnfirm with PNF at 10 ft & 10 kts means Pilot calls "deploy swimmers".
Drop off pass req PNF to set hoist control.
PNF to set hoist control switch Back up pump "on".
PNF to set hoist control switch Hoist mast "on".
Hoist mast "on" should be Located with FE.
Drop off pass req Backenders.
Backenders ready to Operate hoist recovery sys.
Backenders perform Checklist.
Night Water Hoist inludes Lay Pattern Pass.
Lay Pattern Pass req Racetrack Pattern.
Racetrack Pattern will Flyover point.
Flyover point will start Throwing patterns.
Throwing patterns called by PNF to backenders.
PNF to backenders at 2 sec apart.
Throwing patterns means tossing chem lights in water.
tossing chem lights in water provides "runway" reference for Pilots.
Throwing patterns req 100 ft alt & 50 kts AS.
Racetrack Pattern is Comm intensive.
Comm intensive to/from Pilot & copilot.
Comm intensive to Guys in back.
Racetrack Pattern may depend on Moonlight.
Racetrack Pattern in Windline.
Lay Pattern Pass req Series of Low alt passes.
Series of Low alt passes req Pilot fly on instrument.
Pilot fly on instrument airspeed is 50-100 knots.
Pilot fly on instrument means Pilot completely inside.
Pilot fly on instrument means PNF vectors back to point.
PNF vectors back to point means PNF outside cockpit.
PNF outside cockpit to Locate mark.
Locate mark relayed to Pilot flying.
Pilot flying will transition to Outside cockpit.
Outside cockpit can be Dangerous transition.
Dangerous transition due to Disorientation.
Disorientation due to Only one light for reference.
Series of Low alt passes to Get back to point.
Lay Pattern Pass must determine Direction of Wind.
Direction of Wind by Reading wind info on CDU.
Reading wind info on CDU problem is not accurate.
Direction of Wind by Direction of streaks on window.
Direction of Wind drives A/C performance.

A/C performance drives Spray on A/C.
Spray on A/C may require Higher hover alt..
Direction of Wind by comparing Heading & track.
Heading & track done while Navigating to position.
Direction of Wind is Critical.
Critical depends on A/C load.
Direction of Wind is Difficult at night.
Lay Pattern Pass includes Composite Pattern.
Lay Pattern Pass req PNF doing Nav egress.
PNF doing Nav egress is Inside cockpit.
Night Water Hoist includes Observation Pass.
Observation Pass need to Mark survivor.
Mark survivor can be Something in Nav sys.
Something in Nav sys is difficult because Cant put undefined wp as part of flt plan.
Cant put undefined wp as part of flt plan means Storing pt in defined wp's.
Something in Nav sys req PNF keep head down.
Something in Nav sys req Going to CDU.
Going to CDU select Fix page.
Fix page select Flyover store.
Flyover store these steps Cant be performed on way.
Cant be performed on way once there Hit store key over position.
Hit store key over position puts into Data base of sys.
Data base of sys to retrieve Go to flt pln page.
Go to flt pln page then go to Direct flt plan.
Direct flt plan through Assess letter keypad.
Assess letter keypad then Hit letter.
Hit letter then Enter.
Enter then Back to steering.
Mark survivor to Help locate again.
Mark survivor can be Something in water.
Mark survivor has High criticality.
Mark survivor will provide Wind cues (day).
Observation Pass flown at 50-100 ft (night).
Observation Pass flown at 25 ft (day).
Observation Pass to Assess Situation.
Assess Situation is Low Workload.
Assess Situation ie Is there a parachute?.
Assess Situation drives Approach.
Assess Situation ie Is there a fuel spill?.
Assess Situation ie Number of people in water.
Assess Situation ie Determine what service is necessary.
Determine what service is necessary from Knowing package (SOP).
Determine what service is necessary determine Type of extraction.
Type of extraction ie AF horsecollar or penetrator.
Type of extraction ie Navyhooks to harness.

Assess Situation ie Survivor concious?.
Survivor concious? to determine Need to deploy swimmer.
Assess Situation is Highly Critical.

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Appendix B: MH-60G Cockpit Evaluation Questionnaire

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NAME__________________________CREW MEMBER___________

TIME/DATE______________________

PANEL EVALUATION

1. Rate the Pilot/Copilot Control Display Unit using the following scale.

TOTALLY INADEQUATE	VERY INADEQUATE	MILDLY INADEQUATE	MILDLY ADEQUATE	VERY ADEQUATE	TOTALLY ADEQUATE
1	2	3	4	5	6

Rating	Factor	Definition
_____	Access	The accessibility of all of the controls on the panel.
_____	Location	The location of the panel within the crew station.
_____	Display Visibility	The visibility of the panel display.
_____	Lighting	The visibility of the panel lights.
_____	Label/ Legends Legibility	The legibility of the panel labels/ legends.
_____	Functional Grouping	Rate the functional grouping of the panel controls and displays.
_____	Operational Utility	What is your overall impression of the operational utility of the panel?

COMMENTS:

2. Rate the Caution/Warning/Advisory Panel using the following scale.

TOTALLY INADEQUATE	VERY INADEQUATE	MILDLY INADEQUATE	MILDLY ADEQUATE	VERY ADEQUATE	TOTALLY ADEQUATE
1	2	3	4	5	6

Rating	Factor	Definition
_____	Access	The accessibility of all of the controls on the panel.
_____	Location	The location of the panel within the crew station.
_____	Display Visibility	The visibility of the panel display.
_____	Lighting	The visibility of the panel lights.
_____	Label/ Legends Legibility	The legibility of the panel labels/ legends.
_____	Functional Grouping	Rate the functional grouping of the panel controls and displays.
_____	Operational Utility	What is your overall impression of the operational utility of the panel?

COMMENTS:

3. Rate the **Head Down Display** using the following scale.

TOTALLY INADEQUATE	VERY INADEQUATE	MILDLY INADEQUATE	MILDLY ADEQUATE	VERY ADEQUATE	TOTALLY ADEQUATE
1	2	3	4	5	6

Rating	Factor	Definition
_____	Access	The accessibility of all of the controls on the panel.
_____	Location	The location of the panel within the crew station.
_____	Display Visibility	The visibility of the panel display.
_____	Lighting	The visibility of the panel lights.
_____	Label/ Legends Legibility	The legibility of the panel labels/ legends.
_____	Functional Grouping	Rate the functional grouping of the panel controls and displays.
_____	Operational Utility	What is your overall impression of the operational utility of the panel?

COMMENTS:

4. Rate the **TACAN/NAV Control Panel** using the following scale.

TOTALLY INADEQUATE	VERY INADEQUATE	MILDLY INADEQUATE	MILDLY ADEQUATE	VERY ADEQUATE	TOTALLY ADEQUATE
1	2	3	4	5	6

Rating	Factor	Definition
_____	Access	The accessibility of all of the controls on the panel.
_____	Location	The location of the panel within the crew station.
_____	Display Visibility	The visibility of the panel display.
_____	Lighting	The visibility of the panel lights.
_____	Label/ Legends Legibility	The legibility of the panel labels/ legends.
_____	Functional Grouping	Rate the functional grouping of the panel controls and displays.
_____	Operational Utility	What is your overall impression of the operational utility of the panel?

COMMENTS:

5. **Rate the Radios** using the following scale.

TOTALLY INADEQUATE	VERY INADEQUATE	MILDLY INADEQUATE	MILDLY ADEQUATE	VERY ADEQUATE	TOTALLY ADEQUATE
1	2	3	4	5	6

Rating	Factor	Definition
_____	Access	The accessibility of all of the controls on the panel.
_____	Location	The location of the panel within the crew station.
_____	Display Visibility	The visibility of the panel display.
_____	Lighting	The visibility of the panel lights.
_____	Label/ Legends Legibility	The legibility of the panel labels/ legends.
_____	Functional Grouping	Rate the functional grouping of the panel controls and displays.
_____	Operational Utility	What is your overall impression of the operational utility of the panel?

COMMENTS:

6. Rate the **Fuel Management Panel** using the following scale.

TOTALLY INADEQUATE	VERY INADEQUATE	MILDLY INADEQUATE	MILDLY ADEQUATE	VERY ADEQUATE	TOTALLY ADEQUATE
1	2	3	4	5	6

Rating	Factor	Definition
_____	Access	The accessibility of all of the controls on the panel.
_____	Location	The location of the panel within the crew station.
_____	Display Visibility	The visibility of the panel display.
_____	Lighting	The visibility of the panel lights.
_____	Label/ Legends Legibility	The legibility of the panel labels/ legends.
_____	Functional Grouping	Rate the functional grouping of the panel controls and displays.
_____	Operational Utility	What is your overall impression of the operational utility of the panel?

COMMENTS:

7. Rate the Video Symbology Display System (VSDS) Panel using the following scale

TOTALLY INADEQUATE	VERY INADEQUATE	MILDLY INADEQUATE	MILDLY ADEQUATE	VERY ADEQUATE	TOTALLY ADEQUATE
1	2	3	4	5	6

Rating	Factor	Definition
_____	Access	The accessibility of all of the controls on the panel.
_____	Location	The location of the panel within the crew station.
_____	Display Visibility	The visibility of the panel display.
_____	Lighting	The visibility of the panel lights.
_____	Label/ Legends Legibility	The legibility of the panel labels/ legends.
_____	Functional Grouping	Rate the functional grouping of the panel controls and displays.
_____	Operational Utility	What is your overall impression of the operational utility of the panel?

COMMENTS:

8. Rate the **AHHS Control Panel** using the following scale.

TOTALLY INADEQUATE	VERY INADEQUATE	MILDLY INADEQUATE	MILDLY ADEQUATE	VERY ADEQUATE	TOTALLY ADEQUATE
1	2	3	4	5	6

Rating	Factor	Definition
_____	Access	The accessibility of all of the controls on the panel.
_____	Location	The location of the panel within the crew station.
_____	Display Visibility	The visibility of the panel display.
_____	Lighting	The visibility of the panel lights.
_____	Label/ Legends Legibility	The legibility of the panel labels/ legends.
_____	Functional Grouping	Rate the functional grouping of the panel controls and displays.
_____	Operational Utility	What is your overall impression of the operational utility of the panel?

COMMENTS:

9. Rate the **FLIR Control Panel** using the following scale.

TOTALLY INADEQUATE	VERY INADEQUATE	MILDLY INADEQUATE	MILDLY ADEQUATE	VERY ADEQUATE	TOTALLY ADEQUATE
1	2	3	4	5	6

Rating	Factor	Definition
_____	Access	The accessibility of all of the controls on the panel.
_____	Location	The location of the panel within the crew station.
_____	Display Visibility	The visibility of the panel display.
_____	Lighting	The visibility of the panel lights.
_____	Label/ Legends Legibility	The legibility of the panel labels/ legends.
_____	Functional Grouping	Rate the functional grouping of the panel controls and displays.
_____	Operational Utility	What is your overall impression of the operational utility of the panel?

COMMENTS:

10. Rate the SCU using the following scale.

TOTALLY INADEQUATE	VERY INADEQUATE	MILDLY INADEQUATE	MILDLY ADEQUATE	VERY ADEQUATE	TOTALLY ADEQUATE
1	2	3	4	5	6

Rating	Factor	Definition
_____	Access	The accessibility of all of the controls on the panel.
_____	Location	The location of the panel within the crew station.
_____	Display Visibility	The visibility of the panel display.
_____	Lighting	The visibility of the panel lights.
_____	Label/ Legends Legibility	The legibility of the panel labels/ legends.
_____	Functional Grouping	Rate the functional grouping of the panel controls and displays.
_____	Operational Utility	What is your overall impression of the operational utility of the panel?

COMMENTS:

11. Rate the Fuel Boost Pump Control Panel using the following scale.

TOTALLY INADEQUATE	VERY INADEQUATE	MILDLY INADEQUATE	MILDLY ADEQUATE	VERY ADEQUATE	TOTALLY ADEQUATE
1	2	3	4	5	6

Rating	Factor	Definition
_____	Access	The accessibility of all of the controls on the panel.
_____	Location	The location of the panel within the crew station.
_____	Display Visibility	The visibility of the panel display.
_____	Lighting	The visibility of the panel lights.
_____	Label/ Legends Legibility	The legibility of the panel labels/ legends.
_____	Functional Grouping	Rate the functional grouping of the panel controls and displays.
_____	Operational Utility	What is your overall impression of the operational utility of the panel?

COMMENTS:

12. Rate the **Radar TF/Range Control Panel** using the following scale.

TOTALLY INADEQUATE	VERY INADEQUATE	MILDLY INADEQUATE	MILDLY ADEQUATE	VERY ADEQUATE	TOTALLY ADEQUATE
1	2	3	4	5	6

Rating	Factor	Definition
_____	Access	The accessibility of all of the controls on the panel.
_____	Location	The location of the panel within the crew station.
_____	Display Visibility	The visibility of the panel display.
_____	Lighting	The visibility of the panel lights.
_____	Label/ Legends Legibility	The legibility of the panel labels/ legends.
_____	Functional Grouping	Rate the functional grouping of the panel controls and displays.
_____	Operational Utility	What is your overall impression of the operational utility of the panel?

COMMENTS:

13. Rate the Doppler Nav System Display/Control Panel using the following scale.

TOTALLY INADEQUATE	VERY INADEQUATE	MILDLY INADEQUATE	MILDLY ADEQUATE	VERY ADEQUATE	TOTALLY ADEQUATE
1	2	3	4	5	6

Rating	Factor	Definition
_____	Access	The accessibility of all of the controls on the panel.
_____	Location	The location of the panel within the crew station.
_____	Display Visibility	The visibility of the panel display.
_____	Lighting	The visibility of the panel lights.
_____	Label/ Legends Legibility	The legibility of the panel labels/ legends.
_____	Functional Grouping	Rate the functional grouping of the panel controls and displays.
_____	Operational Utility	What is your overall impression of the operational utility of the panel?

COMMENTS:

NAME____________________ CREW MEMBER__FE_____

14. Rate the **Hoist Control** using the following scale

TOTALLY INADEQUATE	VERY INADEQUATE	MILDLY INADEQUATE	MILDLY ADEQUATE	VERY ADEQUATE	TOTALLY ADEQUATE
1	2	3	4	5	6

Rating	Factor	Definition
_____	Access	The accessibility of all of the controls on the panel.
_____	Location	The location of the panel within the crew station.
_____	Display Visibility	The visibility of the panel display.
_____	Lighting	The visibility of the panel lights.
_____	Label/ Legends Legibility	The legibility of the panel labels/ legends.
_____	Functional Grouping	Rate the functional grouping of the panel controls and displays.
_____	Operational Utility	What is your overall impression of the operational utility of the panel?

COMMENTS:

15. Rate the **Stabilator Control Panel** using the following scale.

TOTALLY INADEQUATE	VERY INADEQUATE	MILDLY INADEQUATE	MILDLY ADEQUATE	VERY ADEQUATE	TOTALLY ADEQUATE
1	2	3	4	5	6

Rating	Factor	Definition
_____	Access	The accessibility of all of the controls on the panel.
_____	Location	The location of the panel within the crew station.
_____	Display Visibility	The visibility of the panel display.
_____	Lighting	The visibility of the panel lights.
_____	Label/ Legends Legibility	The legibility of the panel labels/ legends.
_____	Functional Grouping	Rate the functional grouping of the panel controls and displays.
_____	Operational Utility	What is your overall impression of the operational utility of the panel?

COMMENTS:

16. Rate the **Engine Instruments** using the following scale.

TOTALLY INADEQUATE	VERY INADEQUATE	MILDLY INADEQUATE	MILDLY ADEQUATE	VERY ADEQUATE	TOTALLY ADEQUATE
1	2	3	4	5	6

Rating	Factor	Definition
_____	Access	The accessibility of all of the controls on the panel.
_____	Location	The location of the panel within the crew station.
_____	Display Visibility	The visibility of the panel display.
_____	Lighting	The visibility of the panel lights.
_____	Label/ Legends Legibility	The legibility of the panel labels/ legends.
_____	Functional Grouping	Rate the functional grouping of the panel controls and displays.
_____	Operational Utility	What is your overall impression of the operational utility of the panel?

COMMENTS:

17. Rate the **Flight Instruments** using the following scale.

TOTALLY INADEQUATE	VERY INADEQUATE	MILDLY INADEQUATE	MILDLY ADEQUATE	VERY ADEQUATE	TOTALLY ADEQUATE
1	2	3	4	5	6

Rating	Factor	Definition
_____	Access	The accessibility of all of the controls on the panel.
_____	Location	The location of the panel within the crew station.
_____	Display Visibility	The visibility of the panel display.
_____	Lighting	The visibility of the panel lights.
_____	Label/ Legends Legibility	The legibility of the panel labels/ legends.
_____	Functional Grouping	Rate the functional grouping of the panel controls and displays.
_____	Operational Utility	What is your overall impression of the operational utility of the panel?

COMMENTS:

18. Rate the **ICS control panel** using the following scale.

TOTALLY INADEQUATE	VERY INADEQUATE	MILDLY INADEQUATE	MILDLY ADEQUATE	VERY ADEQUATE	TOTALLY ADEQUATE
1	2	3	4	5	6

Rating	Factor	Definition
_____	Access	The accessibility of all of the controls on the panel.
_____	Location	The location of the panel within the crew station.
_____	Display Visibility	The visibility of the panel display.
_____	Lighting	The visibility of the panel lights.
_____	Label/ Legends Legibility	The legibility of the panel labels/ legends.
_____	Functional Grouping	Rate the functional grouping of the panel controls and displays.
_____	Operational Utility	What is your overall impression of the operational utility of the panel?

COMMENTS:

19. Rate the **Mode Select Panel** using the following scale.

TOTALLY INADEQUATE	VERY INADEQUATE	MILDLY INADEQUATE	MILDLY ADEQUATE	VERY ADEQUATE	TOTALLY ADEQUATE
1	2	3	4	5	6

Rating	Factor	Definition
_____	Access	The accessibility of all of the controls on the panel.
_____	Location	The location of the panel within the crew station.
_____	Display Visibility	The visibility of the panel display.
_____	Lighting	The visibility of the panel lights.
_____	Label/ Legends Legibility	The legibility of the panel labels/ legends.
_____	Functional Grouping	Rate the functional grouping of the panel controls and displays.
_____	Operational Utility	What is your overall impression of the operational utility of the panel?

COMMENTS:

20. What task(s) do you feel are the most difficult to accomplish and why?

____

____

____

____

____

____

21. What tasks, if any, do you feel you should have more training on?

____

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____

22. Please describe the type and/or amount of training you feel would be necessary to increase performance in the tasks listed in question 21 above.

____

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Appendix C: MH-60G Hazard Report

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USAF HAZARD REPORT

HAZARD REPORT NO. (Assigned by Safety Office)

1. HAZARD (To be completed by individual reporting hazard)

TO: CHIEF OF SAFETY (Organization and location)

1 SOW/SE

FROM: (Optional - Name, Grade and Organization)

J. D. Smith, TSgt, 55 SOS/OGOV, 4-3330/3611/2/3

TYPE-MODEL, SERIAL NUMBER, A.G.E./MATERIAL/FACILITIES/PROCEDURE OR HEALTH HAZARD INVOLVED

GAU-2B/A, 7.62MM, Minigun System for the MH-60G Helicopter.

DESCRIPTION OF HAZARD (Date, Time, SUMMARY - Who, What, When, Where, How) 12 Jul 93. This is a resubittal of an AF Form 457 dated 4 Nov 91. The original report was submitted while the MH-53/60 minigun systems were grounded for numerous "Hot Guns", caused by breech bolt failures. The intent of the original report was to identifya problem and offer solutions without impeding training or operational capabilities,.since the weapon system was already grounded for other problems.

Since the gun mount on the MH-60 is all metal, should the Gun Control Unit (GCU), Gun Drive Motor, and/or power cables for these components short or be damaged, the gun and mount will become electrified. This happened in Jan 92 and will be explained later in this report. Crewmembers wearing flight gloves have minimal protection from electrical shock, but often the gloves are wet with oil or sweat from preflight duties: the weapons troops seldom wear gloves, if they do, the results would be the same as the aircrew. The GCU mounts on the handgrip assembly and contains triggers, power switch, and power light. The GCU accepts 28 Volts Direct Current (VDC) from the Electronic Control Unit (ECU). When the arming circuit is complete and the trigger pushed, a 28 VDC signal is sent to the ECU to energize the rest of the Alternating/Direct Current componets (AC/DC) for the gun system. The components are the gun drive motor (AC), ammo booster motor (AC), clutch solenoid (DC), last round switch (DC). At start up the gun drive motor (115 VAC, 400 Cycle, 3 Phase) is pushing 40 amperes (amps) for 240 milliseconds and has a steady...

....state current load of 9 amps. One ampere will kill a man!! These and other problems were identified during the initial test/evaluation of the MH-60 minigun system.

RECOMMENDATIONS: SEE ATTACHMENTS.

ATTACHMENT
A. Receipt of original AF Fm 457
B. Excerpt from TAC ATTACK May 79
C. Comments from Initial Test Flt
D. Minigun Handout
1. Minigun electrical data
2. Drawings of H-60 Minigun Drawing 1
3. Drawings of minigun mount Drawing 2
4. Breakdown of M-93 mount
5. Linkage Assembly, M-93
6. Azimuth stop pin, H-60 system
7. Excerpt from G. E. Tech manual Drawing 3
8. Quick Disconnect plug, M-93 Drawings 4 & 5

Continued On Reverse.....

DATE RECEIVED	REVIEWING PERSON (Typed or printed name, grade, and position or title)	SIGNATURE	DESIGNATED OPR
DATE FORWARDED			SUSPENSE DATE

AF FORM 457 SEP 73

HAZARD REPORT ON MH-60G MINIGUN SYSTEM

DESCRIPTION: (CONTINUED)....As mentioned earlier, a power cable on a-minigun mount was chaffed and shorted out during the requal of the minigun in Jan 92. TSgt Smith was manning the left gun and SSgt Hendrix was on the right gun. During a firing pass SSgt Hendrix's minigun malfunctioned. As the gun stopped firing, I could see through my NVGs a bright light reflecting off the cabin walls fore and aft of my gunners window. I looked under my NVGs and could see (bare eyeball) a yellow glow on the cabin walls and by the shadows being cast (thru NVGs/naked eye), I knew the light source was on the right side of the cabin. As I turned and looked toward the Flight Engineer (FE), I could see burning debris blowing through the cabin and past Mr. Brett Reedy (AEL sub-contracting engineer), who was seated aft of SSgt Hendrix. SSgt Hendrix was bathed from his chest down to his knees in a bright yellow light. My initial thought was that Hendrix had a hangfire or other ammunition malfunction in the brass disposal chute, but since there wasn't a corresponding bang that normally accompanies a hangfire and with the burning debris floating through the air, I suspected a major short in the wiring.

When the gun quit, SSgt Hendrix completed his required emergency checklist actions for a gun stoppage. The weapon was cleared and we began to troubleshoot the problem. I instructed Hendrix to check for damage to the power cables and mount. With the cramped quarters we work in, Hendrix did a very thorough search for the source of the problem, but could not see any damage in flight, even with the cabin blue lights on. I checked the circuit breakers (AC circuit protection is provided by a 25 amp circuit breaker) for the guns and none had blown. During this time, Mr. Reedy asked if Hendrix could get a power on light (Indicating the arming circuit was complete, SSgt Hendrix cycled the gun power switch and the pilots cycled the Master Arm/Station & Mode Select switches several times and got a power on light. One attempt was made to fire the weapon. The gun would not rotate. Again Circuit breakers were re-checked. Again no breakers were popped. We dearmed and safed up to return to base. Upon landing, the General Electric Weapons Engineer, Mr Paul Austin, along with gun shop personnel, met us on the ramp.

I had discussed the possibility of this problem with both Reedy and Austin earlier in the day. Their feelings were this never could happen and if it ever did the electricity would run to ground (the mounting point in the gunners window sill). Again we inspected the system thoroughly, with weapon in the firing position and again, even with a well lit parking ramp and using flashlights we could find no damage. We swung the gun mount out of the window (perpendicular to the aircraft's centerline) and I found where the power cable was chaffed down to bare wire by mount components and an area that had signs of the short - 115 VAC/9 AMPS arcing to the mount (see attachment 1).

The mark was about a quarter to three-eighths of an inch in diameter. The area looked like someone had touched an arc welder to it.

The only thing that saved SSgt Hendrix's life that night, was the fact the short occurred low on the mount. Had the short taken place higher on the mount or gun, SSgt Hendrix would've been placed in the path of the electricity as it ran from the short to ground (airframe). Even if the GCU were to short out, the 28 VDC that powers the GCU would give you, at the very least, a nasty jolt (see attachment 1).

RECOMMENDATIONS: Currently we have one of several options to fix this problem of electrical hazards but, we also can fix several other problem areas that are safety and mission related.

1. As a temporary fix, modify the existing mounts handgrip assembly with a rubber spacer to keep the hands off the cross member of the handgrip and add a grip similar to a motorcycle handlebar grip to vertical tubes of the handgrip assembly (see attachment 2). This will do two things:

a. This will insulate the operator or maintainer from the mount and electrical components (see drawing 1).

b. Using the spacer at the bottom of the grip will place the gunner's hand in a better position to track and fire the weapon. The inherent design of the weapon system makes unbalanced, since the handgrips are too long and have too small a diameter for the gunner to smoothly and comfortably train, track, and fire on a given target.

2. Permanent fix #1: Modify the existing support arm (GE part number 218F750) and slider assembly (GE part number 218F996, see attachment 3) to accept the M-93 mount assembly used on the UH-1N and MH-53J (see drawing 2). This will do the following:

a. The M-93 mounting system contains insulated grips, complete with microphone switch and power on light built in to the grips. The M-93 system has been proven over the last twenty plus years to be an extremely reliable and safe system, not to mention user friendly (see attachment 4).

(1) The modification could be done in the field.

(2) Use of the M-93 system will allow both the MH-53 and MH-60 to use the same gun system, eliminating the need and cost to support two totally different gun and mount configurations. This would be very advantageous since both airframes deploy together.

(3) The M-93 system in comparison to the current MH-60 minigun system, is designed with the gunner in mind, the hand grips on the M-93 are contoured to the human hand and it is a well

balanced system. So well balanced in fact that you could, if the situation warranted, train, track, and fire the weapon with only one hand! (One handed shooting is not taught, nor is it encouraged). Compare the current MH-60 minigun system with the E-13 soft mount built during World War II, for the .50 cal machine guns, built with human engineering in mind, (still in use today on all AFSOC helos). The .50 caliber machine with E-13, flash suppressor, and 100 rounds of ammo weighs in at over 100 pounds, yet an average size man could comfortably (if the situation demanded) use one hand to train, track, and fire the fifty with reasonable results. The current design of the hand grips, trigger assembly, and balance of the MH-60 minigun systems requires substantial forces to train, track, and fire the gun, in comparison the M-93 or GAU-18/A (.50 cal) systems.

b. Eliminate the need to further modify the MAU-56/A Delinking Feeder assembly to mount brass and link disposal chutes/conveyers, this will make the system more "User friendly".

(1) Expended brass and links would be disposed of by a hopper and hose assembly (see attachment 4, figure 8-13, part 15).

(2) Links would no longer be ejected into the cabin area, thereby eliminating the present hazard of links working themselves into flight controls or electrical components in the cabin or cockpit areas (see attachment 1).

c. By adapting the M-93 system to the MH-60, the weapons platform would become more versatile, the same system that would mount in the gunners windows could also be moved to a floor mounted pintle for different missions.

d. Configuring the minigun for fixed forward fire mode would consist of positioning the weapon and throwing one mechanical switch, locking the gun down in azimuth and elevation (see attachment 4, figure 8-13, part #11/figure 8-15, part # 16 and attachment 5).

e. Azimuth and elevation stops on the M-93 system are much more reliable and substantially stronger than those on the MH-60 minigun system. The azimuth plate on the yoke assembly of the M-93 has an adjustable azimuth stop that can be easily attached or removed for configurations. The elevation stops also mounts on the uprights of the M-93 yoke and are attached by bolts (see attachment 4, figure 8-13, parts 24/25).

(1) The azimuth and elevation stops on the MH-60 system uses roll pins and/or spring loaded pins in current generation in use at Hurlburt Field. The roll pihs used as the azimuth stop and are easily damaged, broken, and quite often fall out (see attachment 6).

(2) The elevation stop is a spring loaded pin that engages a race milled into the matching face on the yoke assembly.

The stop pin is shouldered type pin and can be easily broken if the gun moved forcibly against the stop, especially if someone gets excited i. e., in a combat situation. Warner-Robbins has authorized the weapons shop to use a spring pin as a suitable substitute if the original elevation stop pin should break. On 28 May 93 and 21 Jun 93, one these spring pins failed in-flight luckily no one was hurt nor was the aircraft damaged. These broken or missing pins were discovered by the crew preflighting the weapons for night mission after the weapons had been fired during day missions.

f. The M-93 saddle assembly offers positive power cable routing and security. The MH-60 system power cable is poor compared to the M-93. The General Electric manual on the MH-60 minigun system contains statements warning about slack in the power cables that might allow the cables to contact the barrel assemblies, in this situation, the hot barrels hot could damage the cables,creating an electrical hazard for the operator (see Attachment 1).

g. The M-93 system is much is easier and quicker to load/arm compared to the MH-60 system. On the M-93 the ammo is fed from the side of the gun. On the MH-60 the gun is canted in the mount and feeds from the bottom of the gun. This requires the gunner to pull the ammo up to the feeder using a screwdriver or other suitable tool. The M-93 system requires no tools to feed ammo to the feeder.

h. On 7 May 93, Aircraft tail no. 014 had a runaway right minigun. Prior to the runaway gun the student flight engineer received a shock from the drive motor cannon plug. The student was troubleshooting the arming circuit due to the gun power on light failing to illuminate; this requires the operator check circuit breakers and cannon plug connections. The student inadvertently left the gun power switch on and when grabbed the drive motor cannon plug to check it , he received a good jolt. We in DOV are investigating this occurrence.

(1) The AC drive modification on both the MH-53 and 60 has the male and female connectors for the gun drive motor and cannon plug on the power cables facing away from the operator. This makes it awkward to connect and disconnect, especially in-flight, plus the window guns on the MH-53 are covered over by the brass/link cover assembly. For both gun systems, this makes difficult it to rapidly remove the power cable cannon plug in the event of a runaway gun.

(2) Attach a "Pig Tail" cable/cannon plug assembly (see drawing 3) that would be safety wired to the drive motor assembly (using the current connector on the AC drive system. The end of the pig tail would be a male connector (like that on the old DC gun drive motor, see attachment 8) and replace the current female cannon plug on the power cable with the quick disconnect type cannon plug that was used on the DC powered gun system and attach by a bracket to either the gun drive motor or preferably to the

mount assembly to allow better/easier access. The locking ring on the quick disconnect could have an insulated bail attached to it, to help lessened the possibility of electrical shock when disconnecting the cannon plug in the event of a runaway gun.

i. The M-93 assembly has a much lower height profile than the current MH-60 minigun system. From the top of the pintle to the top of the saddle assembly, the M-93 measures fifteen inches in height. The MH-60 system measures eighteen inches in height, measured from the slider assembly of the top of the drive motor assembly. The scanning over and around the M-93 will be much easier and inherently increase safety since the crew will have a better field of view.

3. Permanent fix #2: Develop a pintle mount based on the current base plate and pivot arm assembly used for the .50 caliber (see drawing 4/5). The proposed mount would tie into the forward portion of .50 caliber base plate and existing hardware on the cabin floor of the MH-60. This would allow you to do the following:

a. To stow or swing the weapon into firing position would be much quicker, easier, and safer than the present MH-60 minigun system. In the stowed position the current system requires the use of an arm that attaches to slider assembly by a spring loaded pin. The other end is held in the window sill by bungee strap. This arm sits across the gunners knee and puts the barrels in his lap! The other option is to use a cargo tie down strap or cable with carabineers to hold the gun in a stowed fashion (see attachments 6/9/10).

b. The operating system for the pivot/pintle arm is a tried and proven system. Plus the manufacturer of the base plates, pivot arm, and pintle assemblies is Knights Armament located in Vero Beach, Florida.

c. The base/pintle assembly would accept the M-93 system or any other weapons systems that may be added at a future time.

d. The boresighting of the mount would be a lot easier and quicker.

e. When stowed the gun would not block the gunners window or lay across the gunner's lap. With current minigun system the barrels are across your legs or knees. In the event of a hard/crash landing or turbulent air, crewmembers will probably sustain injuries to their extremities.

f. The proposed mount (with the M-93 installed) in the stowed position would put the barrels of the minigun over the top of the .50 caliber in its stowed position. The fifty would have to be stowed first.

g. Using the proposed mount would also be cheaper and easier to maintain and would eliminate the need to use the special safety

interlock switch assembly that mounts in the window sill. A standard micro switch could be used in place either in the window sill or on the base plate/pivot arm assembly (similar to what is used on the MH-53J tail gun mount when miniguns are used on the cargo ramp, see attachment 11).

h. For missions not requiring a .50 caliber, the pivot arm support and pivot arm can be removed leaving the base plate attached and freeing up the door for infiltration and exfiltration missions and devices.

The 7.62 MM minigun by design is an extremely rugged and reliable weapon when mounted and maintained properly. The average Mean Time Between failure for the gun is 25,000 rounds (minimum). I have been firing the minigun for twelve years and have never seen the number and type of problems we've had in testing and operational use as with the MH-60 system. I do not advocate nor recommend the minigun being replaced by a single barrel 7.62 MM weapons system.

The strength and long life of components of the minigun is due to its multi-barrel configuration. The USAF Specail Operations community has proven this time and time again, especially in the Vietnam war. The Huey Gunships of the 20 Specail Operations Squadron were both feared and respected by its enemies. The selective rate of fire and the area which can be covered and saturated in short period of time is nothing less than awesome.

Its flexibility lends itself to offensive roles as in Call For Fire Support missions in an offensive role, but also a heck of a defensive weapon. It was the preferred weapon used on the HH-53s of the Aerospace Rescue and Recovery Service during and after Vietnam.

The M-93 system has been combat proven on the UH-1F/P, UH-1H, UH-1N, HH-53 B/C, and MH-53J. The system was developed for the USAF and was first mounted on the Huey in 1967. It embodies every since of the meaning of "K. I. S. S.":

KEEP IT SIMPLE STUPID!!!!

The primary design of the MH-60 minigun system (BOUGHT FIRST, THEN TESTED, RATHER THAN FLY AND THEN BUY) is that of a fixed forward fire weapon and as an after thought, the U. S. Army and General Electric tried to make it a door gunners weapon. Naturally the Army wanted a weapon like the M-16, a rifle you run over with a tank and still use it. This "GI proofing" of the minigun induced the problems addressed in this report.

The Acquisition system failed the USAF by not consulting with the customer/user before purchase. The logic seemed sound, " Well, the Army's got it on their helicopters, gotta' be good and we'll save time and money cause its already on the shelf", unfortunately we haven't saved money, nor time. Four years later we're still trying fix problems identified in the initial test on the MH-60. Had the

people responsible for acquiring this system procured several systems for testing, before buying sight unseen (more or less), we again wouldn't have expended thousands (maybe millions) of dollars we've spent trying to undo design failures that an experienced gunner could've pointed out during testing before purchase.

With the growing emphasis the USAF is placing on "Total Quality Management" (TQM) - which dictates providing the customer with quality service and products - the user (customer) needs to be brought into the loop prior acquiring equipment which may not fill the bill. The provider of goods and services needs to be sensitive to ensuring any shortfalls in product/services identified by the customer can and will be corrected in a timely and efficient manner to meet the customers mission.

The MH-60 is an ideal weapons platform. All we need is ideal, simple, and reliable equipment to perform our mission. Give us this and we'll continue carry the torch of freedom that was lit by the First Air Commandos during World War Two (the first use of the helicopter in combat was by the First Air Commando Group During World War Two).

Appendix D: Armstrong Labs MH-60G Cyclic & Collective Modification Recommendations

DEPARTMENT OF THE AIR FORCE
ARMSTRONG LABORATORY (AFMC)
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

From: AL/CFHI (Capt Marie Gomes) 16 Dec 92

Subject: Human Factors Considerations for the Proposed Cyclic and Collective Grips

To: WR-ALC/LUHE (Mr. Mickey Moore)

1. I was contacted by Mr. James Daigle, NADEP-Pensacola to provide a human factors assessment of the proposed cyclic and collective grip modifications. I made an initial evaluation and consulted with several colleagues to provide additional input. There were no problems with the proposed changes to the collective grip, but there were two areas of concern with respect to the cyclic grip. The first and most important concern involved changing the ICS control switch to the minigun fire switch. The negative transfer of training effects of this change may lead a pilot to inadvertently fire the gun when he wants to access the ICS. The incidence of negative transfer of training is more apt to occur under conditions of high workload when the operator reverts to previous behavior that was automatic. The second concern deals with the placement of the stick trim switch. Since this switch is used frequently, it should occupy a more easily accessed location that does not require reaching across other controls to activate. In addition, this location may not be suitable for crew members smaller hands who might have to change their hand position on the cyclic to activate this switch.

2. After reaching these initial conclusions, I spoke with Capt. Osborn of SMOTEC/RW to obtain the user's perspective on the requested switch and control placement. He provided me with background information and the constraints that led to the users requesting the proposed design. Based on this input, I now have a better understanding of the rationale behind the changes, but I must continue to express the concerns previously stated. If this prototype is developed it should be adequately tested to determine if the design does pose a safety hazard. I recommend that a safety be incorporated on the minigun fire switch and that crew members receive sufficient training prior to actually flying a live guns mission. In addition, I recommend conducting an anthropometric evaluation of the grip to determine the proper placement of the switches that will accommodate the widest range of pilots hand sizes. Mr. Greg Zehner, (AL/CFHD, DSN 785-8812) one of the Air Force's leading anthropologists, should be consulted.

3. If you have any further questions, please feel free to contact me as DSN 785-7590.

SIGNED

Marie E. Gomes, Captain, USAF
Human Factors Engineer

cc: NADEP (Mr. James Daigle
SMOTEC/RW (Capt Jim Osborn)

U. S. Government Printing Office 1995 650-075/00127

DEPARTMENT OF THE AIR FORCE
AIR FORCE RESEARCH LABORATORY
WRIGHT-PATTERSON AIR FORCE BASE OHIO 45433

10 AUG 2007

MEMORANDUM FOR DTIC-OQ (LARRY DOWNING)
8725 JOHN J. KINGMAN ROAD
FORT BELVOIR VA 22060-6218

FROM: AFRL/HE
2610 Seventh Street
Wright-Patterson AFB OH 45433-7901

SUBJECT: Requesting Distribution Statement Limitation Changed

1. We are requesting that the distribution statement limitation of the document "A Human Factors Evaluation of the MH-60G Pave Hawk Helicopter Cockpit (U), AL-CF-TR-1994-0056" by John J. Spravka et al, be changed from Distribution B to Distribution A. The AD number is B203975. The reason for the change in the distribution statement is that the technical document is unclassified and may be made available to the public. Additionally, the technical document does not contain export-controlled technical data.

2. If you have any questions please contact John Plaga at (937) 255-1166 or e-mail him at john.plaga@wpafb.af.mil.

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